AIR CONDITIONING LOAD PROFILE ANALYSIS

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SUMMARY

This research is concerned with the development of a computer program to evaluate the air conditioning load of a large building. The program utilizes design or actual weather conditions, together with building thermal characteristics and internal usage in its evaluation. It considers the effects of thermal storage and time lag characteristics of opaque walls, as well as the absorption-transmission characteristics of double glass. The program is divided into five parts as follows:

(a) Estimation of solar radiation

(b) Evaluation of solar heat gain factors

(c) Determination of heat gain through opaque walls by transfer-function methods

(d) Evaluation of solar load from fenestration

(e) Use of above programs for cooling load estimation.

The program is primarily designed to generate load profiles on a particular zone and building as a whole, enabling better design of air distribution and air conditioning systems.

NOMENCLATURE

English Letters	Computer Symbols	
CST		central standard time
LCT		local civil time
LST	ST	local solar time
ℓ	AL	latitude
ϕ	TILT	tilted angle
A	A	apparent solar radiation at air mass = 0
B	BB	atmospheric extinction coefficient
C	C	sky diffuse factor
GR	GR	ground reflection
DAY	DAY	number of days from January first
d	D	declination angle
h	H	hour angle
β	BITA	altitude angle
γ	GAMA	azimuth angle
α	WSAZ	wall-solar azimuth
α_{WKO}	SI	wall-solar azimuth with known orientation
θ	AOIN	incident angle
θ_V		incident angle for vertical surface
θ_H		incident angle for horizontal surface
I_{DN}	DNI	direct normal solar intensity
F_{sg}	FSG	angle factor from the roof to the ground

English Letters	Computer Symbols	
F_{ss}	FSS	angle factor from the roof to the sky
I_{ds}	DSI	diffuse radiation from sky falling on the roof
I_{th}	THI	intensity of the solar radiation falling on the ground
I_{dg}	DGI	ground reflection radiation falling on the roof
I_t	TI	total solar radiation falling on the roof
I_D		direct solar radiation
I_d		diffuse solar radiation
I_r		solar radiation reflected from surrounding surface
ψ		zenith angle
R_{go}	RGO	resistance of outside glass
R_{gi}	RGI	resistance of inside glass
T_o	TO	outdoor air temperature
T_i	TI	indoor air temperature
SHGF	SHGF	solar heat gain factor
τ_o	TAUO	transmission of outdoor glass
τ_i	TAUI	transmission of indoor glass
ρ_1	RO1	reflection of outdoor side of outdoor glass
ρ_2	RO2	reflection of indoor side of outdoor glass
ρ_3	RO3	reflection of outdoor side of indoor glass
ρ_4	RO4	reflection of indoor side of indoor glass
α_1	ALP1	absorption of outdoor glass for solar energy incident on outdoor surface

English Letters	Computer Symbols	
α_2	ALP2	absorption of outdoor glass for solar energy incident on indoor surface
α_3	ALP3	absorption of indoor glass for solar energy incident on outdoor surface
α_4	ALP4	absorption of indoor glass for solar energy incident on indoor surface
e_1		total emissivity of the outdoor side of outdoor glass
e_2		total emissivity of the indoor side of outdoor glass
e_3		total emissivity of the outdoor side of indoor glass
e_4		total emissivity of the indoor side of indoor glass
h_o	HO	outdoor surface coefficient of heat transfer
h_i	HI	inner surface coefficient of heat transfer
h_s	HS	air space coefficient of heat transfer
α_o	ALPO	absorption of outdoor glass in a unit
α_i	ALPI	absorption of indoor glass in a unit
U	U	overall coefficient of heat transfer
N_i		inward-flow fraction of the absorbed radiation
N_o		outdoor-flow fraction of the absorbed radiation
E		effective air space emittance
e_o		total emissivity of the outdoor surface of the air space
e_i		total emissivity of the inside surface of the air space
Q		conduction heat flow

English Letters	Computer Symbols	
ΔT		outdoor-indoor temperature difference $(t_o - t_i)$
q_{RCi}	QRCI	rate of heat flow by radiation and convection inward
q_{RCo}	QRCO	rate of heat flow by radiation and convection outward
$I_t\tau$		transmitted radiation
$I_t\rho$		reflected outward radiation
$I_t\alpha$		absorbed solar radiation
t_o		outdoor air temperature
t_i		indoor air temperature
N_{io}		inward flowing fraction of absorbed radiation from outside glass (U/h_o)
N_{ii}		inward flowing fraction of absorbed radiation from indoor glass $(U/h_o + U/h_s)$
q_R		heat reflected
q_S		heat stored
q_T		heat transmitted
q_A		the instantaneous rate of heat admission through the fenestration
$I_D\tau_D$		radiation transmitted through glass by direct radiation
$I_d\tau_D$		radiation transmitted through glass by diffuse radiation
t_{go}	TGO	temperature of the outside glass
t_{gi}	TGI	temperature of the inside glass
F	F	the dimensionless ratio of the solar heat gains to the incident solar radiation
SC	SC	shading coefficient

English Letters	Computer Symbols	
t_s	TS	surface temperature
ε		emittance of the surface
ΔR		the difference between the long wave radiation incident on the surface from the sky and surroundings and the radiation emitted by a black body at outdoor temperature
t_e	TSAT	sol-air temperature
t_{ev}		sol-air temperature for vertical surface
t_{eh}		sol-air temperature for horizontal surface
$q_e\tau$		heat gain by the room through indoor surface of a wall or roof
A	A	indoor surface area of a wall or roof
τ	TAU	time
ℓ	BL	direction cosines of normal to surface (vertical line)
m	BM	direction cosines of normal to surface (horizontal line pointing west)
n	BN	direction cosines of normal to surface (horizontal line pointing south)
a_j	AA	coefficient for regular double strength sheet glass for use in computer calculation of transmittance
t_j	T	coefficient for regular double strength sheet glass for use in computer calculation of absorptance
Δ		time interval
n		summation index (each summation has as many terms as there are non-negligible values of coefficients)
$t_{e,\tau-n\Delta}$		sol-air temperature at time τ-nΔ, Fahrenheit

English Letters	Computer Symbols	
t_{rc}	TR	constant indoor room temperature
b_o	BO	
d_o	DO	transfer function coefficients
c_o	CO	
$q_{p,r}$		heat gain by the room through the interior partitions, ceiling and floors
t_b	TB	air temperature of adjusting space
q_{el}		the instantaneous rate of heat gain from electric lighting
q_{em}		the instantaneous rate of heat gain from electric motor
q_s		sensible heat gain
q_ℓ		latent heat gain
R_H		relative humidity
V_e		equivalent wind velocity, mph
V		wind velocity normally calculated for location, mph
a		distance window is above mid-height, ft
b		distance window is below mid-height, ft
	HPSS	number of possible hours of sunshine
	KKKK	number of days considered in calculation
	NMAX	number of hours
	NWALL	number of walls
	QE	heat gain by the room through the interior partitions, ceilings and floors
	TSI	total solar intensity
K_T		conductance, Btu/hr-ft^2-°F

L_F Length of room exterior wall

Subscripts

w window

ow outside wall

c corridor

CHAPTER I

INTRODUCTION

The currently used methods for estimating the heat transfer rates through floors, walls and roofs of buildings are largely based upon a steady-state heat flow concept (equivalent temperature difference). The engineering application of these concepts is not complicated and has served well for many years in the process of design and selection of heating and cooling equipment for buildings. However, competitive practices of the building industry sometimes require much more than just a selection or design of a single heating or cooling system. Consulting engineers are often required to present a detailed comparison of alternative heating and cooling systems for a given building, including initial costs as well as short and long-term operating and maintenance costs. The degree of sophistication required for cost estimation may make it necessary to calculate the heating and cooling load in hourly increments, say for a year's time for given buildings at known geographic locations. Because of the large number of calculations that are involved, computer processing becomes necessary. The hour-by-hour heating and cooling load calculations, when based upon a steady heat flow concept, do not account for the heat storage effects of the structural elements, especially when one is interested in the net heat gain to the air conditioned spaces.

The procedure that is generally utilized to calculate cooling loads is to consider the sources one at a time and to evaluate their effect on the cooling load. In general, the building may be broken into zones to facilitate zone control. For each zone, design conditions must be specified. They are:

(A) Desired indoor conditions

(B) Prevailing outdoor conditions

(C) Prescribed ventilation rate

These design conditions include temperatures, humidities, solar radiation, exposed wall areas and their thermal characteristics, fenestration areas and their transmission characteristics, room occupancy, lighting and appliances. From these conditions it is possible to determine the magnitude of cooling load for the zone caused by each of the sources. These sources are:

(A) Solar radiation transmitted through walls, roofs, glass areas, etc.

(B) Outdoor-indoor temperature difference causing conduction load through walls, doors, glass, etc.

(C) Heat gain through interior partitions (results from unconditioned spaces adjacent to the room being conditioned or adjacent spaces with different temperatures).

(D) Heat and moisture gain due to natural and mechanical ventilation (results in both sensible and latent load as a result of indoor-outdoor wet bulb and dry bulb temperature differences).

(E) Heat sources within conditioned space (typical examples are people, lights, power equipment and appliances).

(F) Moisture transfer through permeable materials (results from the vapor pressure difference between inside and outside).

(G) Miscellaneous heat sources (includes all classifications of heat gains from exposed pipes, ducts, work done by the circulating fan, etc.).

The philosophy adopted in developing the computer program was one of providing the capability of calculating the cooling load using these sources continuously without the necessity for repeated references to tables. Thus, once the characteristics of the building have been fixed, the computer program will be able to compute the cooling load for each of the 24 hours of any day, both for individual rooms and the building as a whole.

Advantages of a Computer Program Over the Manual Method

The object of the calculation is to find the maximum cooling load at any time throughout the year. For this to be accurate, calculations must be performed for several times during the year and also several times during the day.

Where manual calculations are performed, selection of the hour of the day and the day of the year is left largely to the judgement of the person making the calculation. The computer program calculates loads for the entire day and can easily calculate loads for many different days of the year, thereby eliminating uncertainty. In addition, the use of the computer program increases the accuracy of cooling load analysis. This is accomplished by including the heat capacity effects of walls and floors in the load calculations and by replacing tabulated data with results from more accurate formulas. The prime examples are use of equations in the computer program for determining the direct solar radiation and solar heat gain factors. The published tables are limited to the time of the day and day of the year for a few selected latitudes but the formulas apply for any given day of the year and any latitude.

Comparison of Methods Used in Cooling Load Calculations

The method usually employed to calculate cooling loads for large buildings is recommended in *ASHRAE Handbook of Fundamentals* and *ASHRAE Guide and Data Book*. For residential installations, it is common to use a simplified version of this method. This is suggested in the *ASHRAE Handbook of Fundamentals* and is more completely outlined in Manual J of the National Warm Air Heating and Air Conditioning [34]. In both of these approaches, as well as the computer program approach, the calculations are directed toward obtaining a maximum load for purposes of design and selection of equipment. However, without a computer program, factors which would tend to moderate the load, such as the heat capacity of structures and the effects of cloud covers are generally omitted. The calculation method employed in these simplified approaches is to select design conditions, listed above, and to use appropriate factors and coefficients given in tables in the ASHRAE Handbook of Fundamentals or Manual J [34] to calculate the magnitude of each of the particular load sources. The result is the cooling load for the hour of the day and the day of the year selected for the design conditions. If the engineer suspects that a greater load might be attained on a different day or at a different hour, either for the building as a whole or for an individual room, he must repeat the calculations with factors from tables appropriate to the new time. Such repetitive calculations are usually necessary with fenestration.

One of the advantages of the computer technique over the other two methods is the ability of the computer to rapidly and inexpensively present loads from various sources as a function of time. In the computer technique, the position of the sun is calculated continuously in order to permit evaluation of angle of incidence, the time when walls are exposed to the sun, and shading effects.

The cooling load can be calculated more accurately by use of the "Sol-Air Method" [3]. The heat gains through opaque wall and roof elements are calculated by using the appropriate sol-air temperature data and the associated wall heat transfer function. The transfer function coefficients for many widely used types of walls and roofs are listed in Tables 39 and 40 of the 1972 ASHRAE Handbook of Fundamentals [3].

The main advantage of the procedure presented here, however, is that it takes the calculation a step beyond the determination of cooling load and evaluates the rate at which heat will be removed from a space and the temperature of the space when a specified size and type of cooling unit is used. This phase of the analysis also allows the designer to evaluate the effects of different schedules of operation. This was not possible with the old methods. By enabling the designer to evaluate the deviations of room air temperature from the nominal design value, this method permits him to exploit the finite width of the comfort zone and select equipment that can maintain conditions within the zone, although not always at the center of the zone.

The computer program developed in this thesis has been used to evaluate the cooling load for only four consecutive days, for each hour of the day instead of a 8760 hour year long cooling load analysis. The computer programs developed herein are capable of calculating the sunrise, sunset, solar angles, solar radiation, solar heat gain factors, heat gain through fenestrations, heat gain through walls and partitions, and cooling load caused by heat gains. These calculations could be done on an hourly basis for each hour of the selected day.

CHAPTER II

THEORY

A. Introduction

The theory outlined in this chapter concerns the heat gain of a zone or the building as a whole influenced by solar heat gain, conduction heat gain, heat gain by the internal heat sources, and finally the ventilation and/or infiltration gains. In order to estimate the heat gain due to direct solar radiation, it is necessary to set forth the relations among the sun, earth, locality, time of the day, and orientation. It is also necessary to establish the amount of direct and diffuse solar radiation received by the earth's surface with respect to various orientation. The conduction heat gain is influenced by the selected external and internal selected design conditions. Heat gain by the internal heat sources is influenced by the density of the occupancy, lighting, equipment, and appliances in the conditioned space. The theory described here is based on the data and procedure outlined in <u>ASHRAE Handbook of Fundamentals 1972</u> [3]. It contains detailed discussion of solar heat gain factors and transfer function methods for opaque walls which permit accurate accounting to determine the cooling loads of a zone or entire building.

B. The Earth

The earth revolves about the sun in an elliptical (nearly circular) orbit, with the sun located at one of the foci. The earth's mean distance from the sun is approximately 92,900,000 miles. About January 1, the earth is closest to the sun, while on about July 1, it is most remote, being about 3.3 percent further away. The earth's axis of rotation defining north and south, is tilted 23.5 degrees with respect to its orbital plane about the sun. In its orbital movement, the earth keeps this axis oriented in the same direction. Earth's rotation about its axis and the orbital motion account for the distribution of solar radiation over the earth's surface, the changing length of hours of daylight and darkness, and the changing of the seasons, as shown in Figures 1 and 2.

Figure 1 schematically shows the effect of the earth's tilted axis at various times of the year. Figure 2 shows the position of the earth relative to the sun's rays at the time of the winter solstice. At the winter solstice (December 22, approximately), the North Pole is inclined 23.5 degrees away from the sun. All other points on the earth's surface north of 66.5 degrees north latitude are in total darkness for 24 hours each day, while all regions within 23.5 degrees of the South Pole receive continuous sunlight. At the time of the summer solstice (June 22, approximately), the situation is reversed. At the time of the two equinoxes

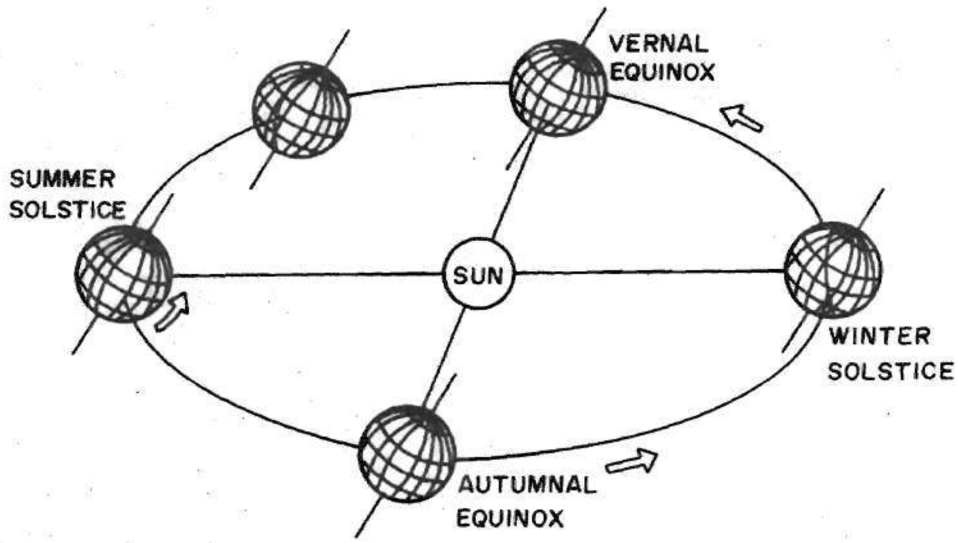


FIGURE 1 THE EARTH REVOLUTION ABOUT THE SUN.

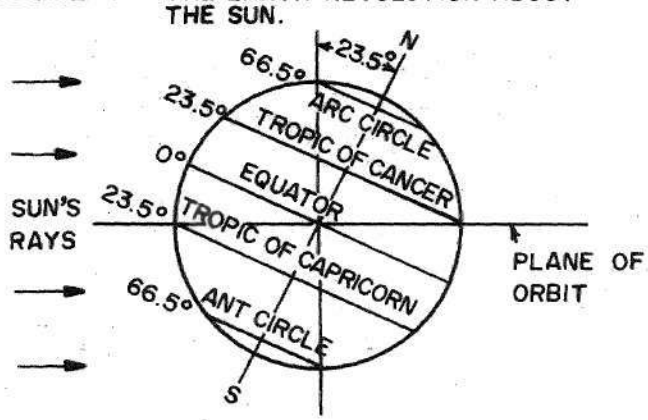


FIGURE 2 POSITION OF EARTH IN RELATION TO SUN'S RAYS AT THE TIME OF THE WINTER SOLSTICE.

(March 22 and September 22, approximately), both poles are equidistant from the sun and all points on the earth's surface have 12 hours of daylight and 12 hours of darkness.

C. Time

Solar radiation calculations must be made in terms of solar time, while the standard time with which we are more familiar is based on civil time. Whereas a civil day is precisely 24 hours, a solar day varies somewhat in length, due to irregularities in the earth's rotation, the ellipticality of the earth's orbit, and other factors.

The difference between Local Solar Time (LST) and Local Civil Time (LCT) is called the Equation of Time. Thus

$$\text{LST} = \text{LCT} + \text{Equation of Time} \tag{1}$$

$$= \text{ST} + \text{Equation of Time} + \text{Longitude Correction} \tag{2}$$

where ST is the standard time. Longitude correction is necessary if the local longitude is not an integral multiple of 15. Table 1 shows weekly values of the Equation of Time for the year 1950 [12]. For practical purposes, these values may be used for any year. For any one day, the Equation of Time may be considered constant.

At a given locality, standard time may differ from civil time. Clocks are usually set for the same reading

Table 1. Equation of Time

DAY →	1	8	15	22
MONTH	EQ. OF TIME MIN·SEC	EQ. OF TIME MIN·SEC	EQ. OF TIME MIN·SEC	EQ. OF TIME MIN·SEC
JANUARY	-(3:16)	-(6:26)	-(9:12)	-(11:27)
FEBRUARY	-(13:34)	-(14:14)	-(14:15)	-(13:41)
MARCH	-(12:36)	-(11:04)	-(9:14)	-(7:12)
APRIL	-(4:11)	-(2:07)	-(0:15)	1:19
MAY	2:50	3:31	3:44	3:30
JUNE	2:25	1:15	-(0:09)	-(1:40)
JULY	-(3:33)	-(4:48)	-(5:45)	-(6:19)
AUGUST	-(6:17)	-(5:40)	-(4:35)	-(3:04)
SEPTEM.	-(0:15)	2:03	4:29	6:58
OCTOBER	10:02	12:11	13:59	15:20
NOVEMB.	16:20	16:16	15:29	14:02
DECEMB.	11:14	8:26	5:13	1:47

throughout an entire zone covering about 15 degrees of longitude. The United States is divided into four time zones, with the time kept in each zone being the Local Civil Time of a selected meridian near the center of the zone. Such time is called Standard Time. The four standard meridians in the United States are at west longitudes of 75 degrees (Eastern Standard Time (EST)), 90 degrees (Central Standard Time (CST)), 105 degrees (Mountain Standard Time (MST)), and 120 degrees (Pacific Standard Time (PST)). In many localities, clocks are advanced one hour beyond Standard Time in summer. In the United States, such time is called Daylight Saving Time.

D. Earth-Sun Angles

The position of point (P) on the earth's surface and its angles with respect to the sun's rays is known at any instant if the latitude (ℓ) and hour angle (h) for the point, and the sun's declination (d) are known. These angles are shown by Figure 3. Point (P) represents a location on the northern hemisphere.

1. Sun's Declination (d)

The sun's declination (d) is the angular distance of the sun's rays from the celestial equator (north or south). As shown in Figure 3, the sun's declination is the angle formed at solar noon between a vector parallel to the sun's rays which would intersect the center of the earth and the

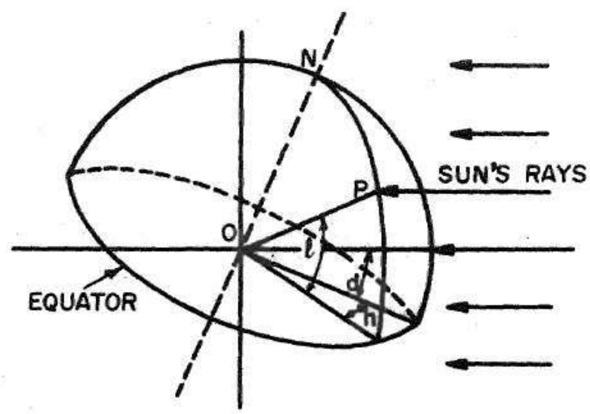


FIGURE 3 LATITUDE, HOUR ANGLE, AND SUN'S DECLINATION.

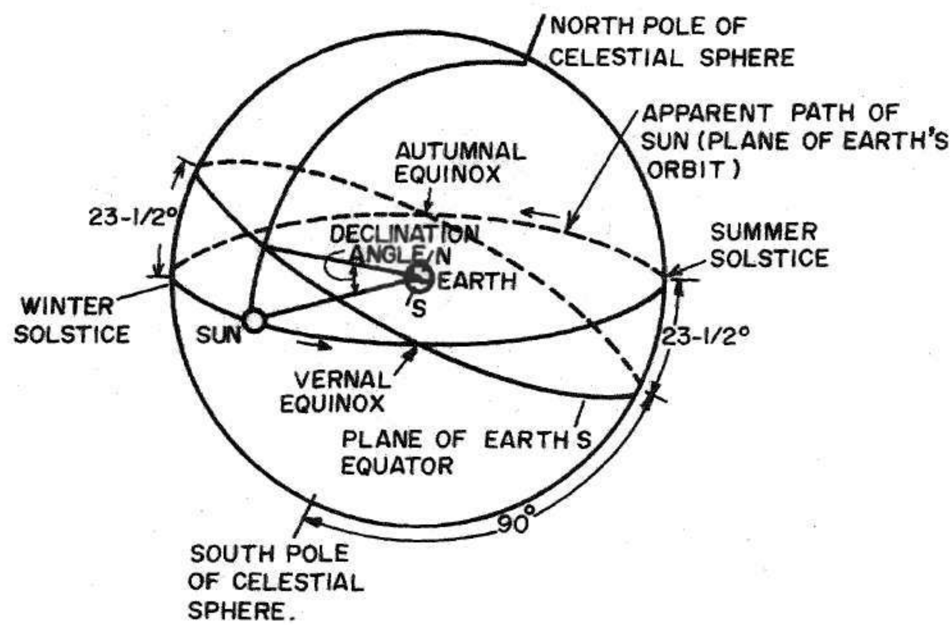


FIGURE 4 SCHEMATIC CELESTIAL SPHERE SHOWING APPARENT PATH OF SUN AND SUN'S DECLINATION ANGLE.

projection of this vector upon the earth's equatorial plane. The tilt of the earth's axis with respect to its orbital plane is the direct cause of the sun's declination [12]. The sun's declination is a function of date.

Figure 4 shows a schematic celestial sphere where the earth is taken as the center of the universe [12]. The sun would appear to move in the plane of the earth's orbit. Figure 4 shows the sun's angle of declination. At the time of the winter solstice, the sun's rays would be 23.5 degrees south of the earth's equator (d = -23.5). At the time of the summer solstice, the sun's rays would be 23.5 degrees north of the earth's equator (d = 23.5). At the equinoxes, the sun's declination would be zero. Figure 5 shows approximately the variation of the sun's declination throughout the year. Because the period of the earth's completed revolution about the sun does not coincide exactly with a calender year, the declination varies slightly on the same day from year to year. For one day, the declination may be assumed constant.

$$d = \left(\begin{matrix}\text{latitude of the} \\ \text{tropic of cancer}\end{matrix}\right) \times \sin\left(360/365\,(D-80)\right)$$

$$d = 23.5 \sin\left(360/365\,(D-80)\right) \qquad (3)$$

$$\text{where } -23.5 \leq d \leq +23.5$$

For the summer period (between the vernal and autumnal equinoxes), the sign of declination is positive (+); for other times, the sign would be negative (-).

In order to show the other angles, consider Figure 6, which demonstrates that to an observer on the earth, the sun appears to move across the sky, following the path of circular arc from horizon to horizon.

2. Latitude (ℓ)

The latitude (ℓ) is the angular distance of the point (p) north (or south) of the equator. In Figure 3, it is the angle between the radius vector $\overline{OP}$ and the projection of $\overline{OP}$ on the equatorial plane. Point (0) represents the center of the earth. Attention must be given to correct sign for latitude. If north latitudes are considered, the sign is positive (+), and if south latitudes are considered, the sign is negative (-).

3. Zenith Angle (ψ)

The sun's Zenith angle (ψ) is the angle between the sun's rays and a line perpendicular to the horizontal at (P) (extension of $\overline{OP}$).

$$\cos\psi = \cos(\ell)\cos(h)\cos(d) + \sin(\ell)\sin(d) \qquad (4)$$

(See Appendix B for derivation.)

4. Hour Angle (h)

The hour angle (h) is the angle through which the earth must turn to bring the meridian of (P) directly in

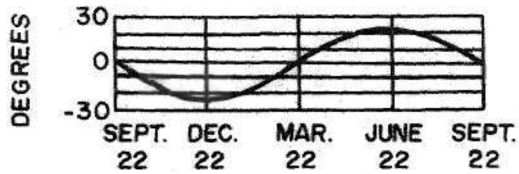


FIGURE 5 VARIATION OF SUN'S DECLINATION.

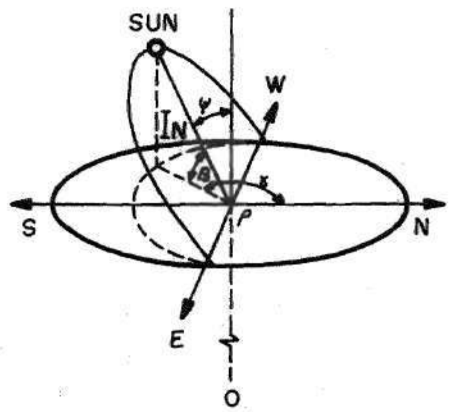
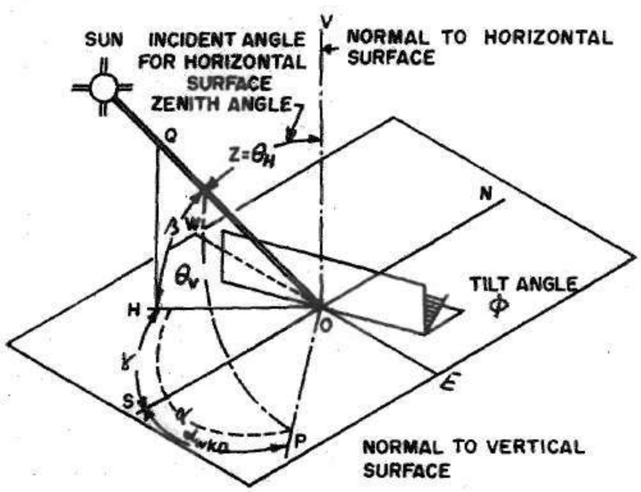


FIGURE 6 DEFINITION OF SUN'S ZENITH, ALTITUDE, AND AZIMUTH ANGLES.



SOLAR ALTITUDE, $\beta = \angle QOH$

ZENITH ANGLE, $Z = \angle QOV$

WALL AZIMUTH, $\alpha_{wk\bar{o}} = \angle SOP$

SOLAR AZIMUTH, $\gamma = \angle SOH$

INCIDENT ANGLE, $\theta_V = \angle QOP$

WALL-SOLAR AZIMUTH $= \angle HOP$

FIGURE 7 SOLAR ANGLES FOR VERTICAL & HORIZONTAL SURFACES line with the sun's rays as shown in Figure 3. At noon (solar time) the hour angle is zero. The hour angle expresses the time of day with respect to solar noon. One hour of solar time equals 360/24 or 15 degrees (or 0.25 minute) of hour angle.

$$h = 0.25 \text{ X (number of minutes from local solar noon)} \qquad (5)$$

The hour angle measured on either side of solar noon, therefore, is

$$0 < h < \pi$$

5. Altitude Angle (β)

The altitude (β) is the angle in a vertical plane between the sun's rays and the projection of the sun's rays on the horizontal plane.

$$\sin(\beta) = \cos(\ell)\cos(h)\cos(d) + \sin(\ell)\sin(d) \qquad (6)$$

(See Appendix B for derivation.) From equations 4 and 6, it can be seen that $\psi = 90-\beta$.

6. Azimuth Angle (γ)

The azimuth angle (γ) is the angle in the horizontal plane (i.e., horizon plane of the locality) measured from north to the horizontal projection of the sun's rays.

$$\cos\gamma = \sec\beta\ (\cos d \sin\ell \cos h - \cos\ell \sin d) \tag{7}$$

(See Appendix B for derivation.) Azimuth is measured counterclockwise from the south for hour angles before solar noon and clockwise from the south for hour angles after solar noon.

In calculations involving other than horizontal surfaces, it may be convenient to express the sun's position relative to the surface in terms of incidence angle (θ). For vertical surfaces, use of the wall-solar azimuth (α) also may be helpful. Figure 7 shows a surface tilted by an angle (ϕ) from the vertical position.

7. Tilted Angle (ϕ)

The tilted angle (ϕ) is the angle between the surface (tilted surface) and the vertical surface.

8. Wall-Solar Azimuth (α)

The wall-solar azimuth (α) is the angle measured in horizontal plane between the normal to the vertical surface and the horizontal projection of the sun's rays. The values of the wall-solar azimuth for eight orientations are listed in Table 2 below.

The wall-solar azimuth is associated with a definite vertical wall position and it may be found from the sun's azimuth (γ). Therefore, to find the wall-solar azimuth for other orientations:

Table 2. Wall Orientations and Azimuths, Measured from the South

Orientation	N	NE	E	SE	S	SW	W	NW
Wall-Solar Azimuth (α_{WKO})	180	135	90	45	0	45	90	135

(a) For walls facing east of south

$$\alpha = \gamma - \alpha_{WKO} \text{ (a.m.)}$$
$$\alpha = \gamma + \alpha_{WKO} \text{ (p.m.)} \quad (8)$$

(b) For walls facing west of south

$$\alpha = \gamma + \alpha_{WKO} \text{ (a.m.)}$$
$$\alpha = \gamma - \alpha_{WKO} \text{ (p.m.)} \quad (9)$$

Where (α_{WKO}) is the wall-solar azimuth with known orientations. Values of (α_{WKO}) are given in Table 2. Treat negative values of (α) as if they were positive. If (α) is greater than 90 degrees, the surface does not see the sun directly.

9. Angle of Incidence (θ)

The angle of incidence (θ) is the angle between the incoming sun's rays and a line normal to that surface (tilted surface). For the horizontal surface in Figure 7, the incidence angle (θ_H) is $Q\hat{O}V$; for the vertical surface, the incidence angle (θ_V) is $Q\hat{O}P$. The angle of incidence is associated with a definite surface position. For any surface, the incidence angle (θ) is related to altitude, wall-solar azimuth, and the tilted angle of the surface by

$$\cos\theta = \cos\beta \cos\alpha \cos\phi + \sin\beta \sin\phi \tag{10}$$

When surface is vertical, $\phi = \frac{\pi}{2}$, then

$$\cos\theta_V = \sin\beta \tag{10a}$$

When surface is horizontal, $\phi = 0$, then

$$\cos\theta_H = \cos\beta \cos\alpha \tag{10b}$$

E. Solar Radiation

About one two-billionth of the sun's radiation impinges on the earth, but about half of this is radiated into interstellar space by our atmosphere. We receive at the earth's surface 10^{18} hp-hr per annum [18]. When solar radiation passes through the atmosphere, part of it is absorbed by constituents such as carbondioxide, ozone and water vapor, and scattered by dust particles, resulting in diffuse radiation coming from practically all directions.

The transmitted radiation, after the above mentioned absorption and scattering effects are taken into account, is referred to as direct radiation. A portion of scattered radiation is transmitted to the earth from the entire sky vault which is termed diffuse radiation. The relationship between the direct and diffuse radiation at any point on the earth is dependent on the following two factors:

(1) The path of the solar beam through the atmosphere to reach a point on the earth.

(2) The amount of haze in the air.

As the direct radiation and/or the diffuse radiation varies because of the above factors, it affects the total quantity of heat reaching the earth's surface [1,2,3,9,12,18].

The total radiation (I_t), reaching the terrestrial surface is the sum of the direct solar radiation (I_D), the diffuse sky radiation (I_d), and the solar radiation reflected from the surrounding surface (I_r).

$$I_t = I_D + I_d + I_r \text{ Btu/hr-ft}^2 \tag{11}$$

The intensity of the direct component is the product of the direct normal irradiation (I_{DN}), and the cosine of the angle of incidence (θ), between the incoming solar rays and a line normal (perpendicular) to the surface [3].

$$I_D = I_{DN} \cos\theta \text{ Btu/hr-ft}^2 \tag{12}$$

Thus,

$$I_t = I_{DN} \cos\theta + I_d + I_r \quad Btu/hr\text{-}ft^2 \tag{13}$$

1. Direct Normal Solar Intensity, I_{DN}

The value of I_{DN} at the surface of the earth on a clear day is represented by

$$I_{DN} = \frac{A}{\exp\ (B/\sin\beta)} \quad Btu/hr\text{-}ft^2 \tag{14}$$

where

A = apparent solar irradiation (at air mass = 0)

B = atmospheric extinction coefficient.

The values of A and B vary during the year because of seasonal changes in the dust and water vapor content of the atmosphere, and also because of the changing earth-sun distance. The variations in values A and B are listed in Table 2. These data will not give the maximum value of I_{DN} that can occur in each month, but rather are representative of conditions on average cloudless days. For very clear atmospheres, the value of I_{DN} can be as much as 15 percent higher than is indicated by equation (14) and Table 3 should be multiplied by clearness factors [19] given in Figure 8.

2. Diffuse Solar Radiation, I_d

The diffuse solar radiation from a clear sky that falls on any surface is given by equation (15).

Table 3. Variation of A's and B's Throughout the Year

DATE	A Btuh/ft^2	B AIR MASS^{-1}	C (DIMENTIONLESS)
JAN 21	390	0.142	0.058
FEB. 21	385	0.144	0.060
MAR.21	376	0.156	0.071
APR.21	360	0.180	0.097
MAY 21	350	0.196	0.121
JUNE 21	345	0.205	0.134
JULY 21	344	0.207	0.136
AUG.21	351	0.201	0.122
SEPT.21	365	0.177	0.092
OCT.21	378	0.160	0.073
NOV.21	387	0.149	0.063
DEC.21	391	0.142	0.057

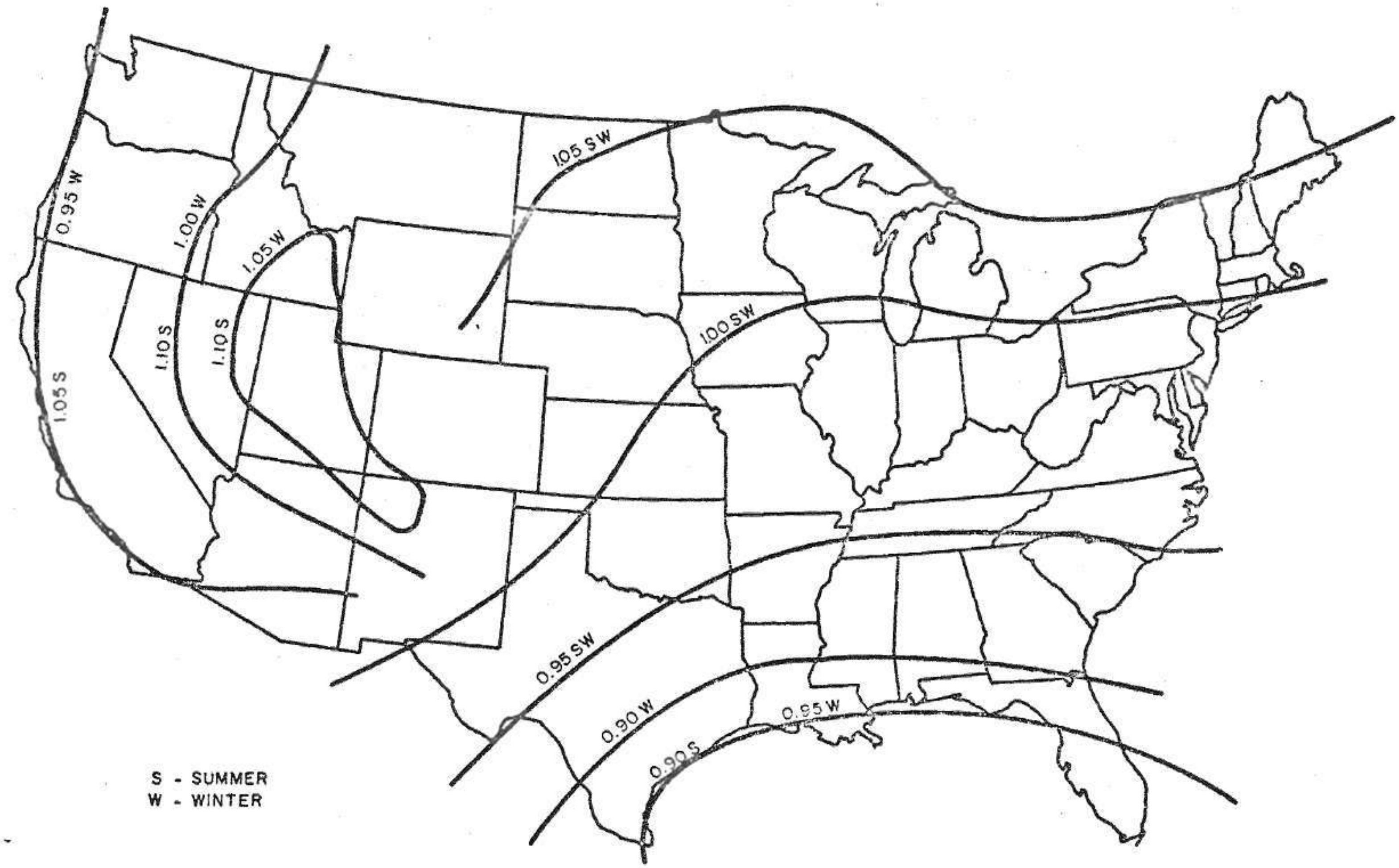


Figure 8. Estimated Atmospheric Clearness Numbers in the U. S. for Nonindustrial Localities

$$I_d = CI_{DN} F_{ss} \quad \text{Btu/hr-ft}^2 \tag{15}$$

where

C = the diffuse radiation factor given in Table 3

F_{ss} = the angle factor between the surface and sky, i.e., the fraction of the radiation emitted by the surface that goes directly to the sky.

The solar radiation that reaches a surface by diffuse reflection at an adjacent surface is the intensity falling on the reflecting surface times its reflectance multiplied by the angle factor between the receiving surface and the reflecting surface. The angle factor that is commonly encountered is reflection from the ground to an inclined surface. For this case the angle factor is

$$F_{sg} = (1-\cos\phi)/2 \tag{16}$$

The angle factor from a surface to the sky can be obtained most easily from the fact that the sum of all the angle factors from a surface to its surroundings equals 1.0. Therefore, the angle factor between the surface and sky is given by

$$F_{ss} = 1-F_{sg} \tag{17}$$

If it is flat roof, i.e., $\phi = 0$

then

$$F_{ss} = 1$$

therefore,

$$I_d = C\, I_{DN} \tag{18}$$

The intensity of the solar radiation falling on the ground is

$$I_{tH} = I_{DN}\,(C + \sin\beta) \tag{19}$$

The ground reflection on the roof is given by

$$I_{dg} = I_{tH} \times F_{sg} \times GR \tag{20}$$

where

GR = percent of the ground reflectance

If it is flat roof, i.e. $\phi = 0$, then $F_{sg} = 0$ and hence,

$$I_{dg} = 0 \tag{21}$$

If a digital computer is used, it is more convenient to have these equations and data that were used in evaluating the tables rather than the tabular values themselves. The computer can then be programmed to evaluate the solar angles and the solar radiations for the specified orientation, the time of the day and the day of the year.

F. Heat Gain

1. Solar Heat Gain by Heat Transfer Through Fenestration Area

The ability of glazing materials to transmit solar radiation depends upon wavelength of the radiation, the chemical composition and thickness of the material, and the incident angle. At any instant, the total solar radiation, I_t falling on a window must be equal to the radiation which is transmitted ($I_t\tau$), reflected outward ($I_t\rho$), and absorbed ($I_t\alpha$). The values of the solar optical properties (transmittance, τ; reflectance, ρ; and absorptance, α) depend upon the thickness, physical properties and chemical composition of the glazing material, or coating which may be applied to its surfaces, and the incident angle, θ[21].

Heat transfer through fenestration area is affected by many environmental factors, of which the most significant of all are:

(a) Total solar radiation intensity (I_t) and incident angle, θ.

(b) Outdoor-indoor temperature difference.

(c) Velocity and direction of air flow across the exterior and interior fenestration surfaces.

The surface heat transfer coefficients h_o and h_i include the combined effects of radiation and convection. When there is forced air motion, caused by wind on the outdoor surface and air induction devices or fans at the indoor surfaces, the heat transfer coefficients increase, causing the overall coefficient U to increase and altering the inward-flow fraction N_i. For summer conditions, the recommended value of wind velocity is 7.5 mph, and the corresponding value of the outer surface coefficient (h_o) is 4.0 Btu/hr-ft^2°F. For natural convection at the inner surface of a vertical window, the inner surface coefficient (h_i) is usually close to 1.46 Btu/hr-ft^2°F [3].

For an insulating glass panel made up of glass with no reflective coating on the air space surface, a vertical air space coefficient (h_s) of 1.3 Btu/hr-ft^2°F is used. When a reflective coating is used on the air space surface, (h_s) can be selected from Table 9 of the ASHRAE Handbook (3, page 396), by first calculating the effective air space emittance (E) and determining the value of air space thickness. Effective air space emittance may be obtained by:

$$\frac{1}{E} = \frac{1}{e_s} + \frac{1}{e_1} = 1 \tag{22}$$

(d) Low temperature radiation exchange between the surfaces of the fenestration and the surroundings.

For predicting instantaneous rates of heat flow through fenestration, it is usually assumed that the outside surroundings are at the outdoor air temperature. The radiation heat exchange is then included in the outer and inner surface coefficients (h_o) and (h_i).

In the absence of sunlight, heat flows through fenestration by thermal conduction [3].

$$q = U(\Delta T) \tag{23}$$

When the outdoor temperature (t_o) is higher than the indoor temperature (t_i), the conduction heat flow is inwards, but when the outdoor temperature is lower than indoor temperature, then the conduction heat flow is outward.

When the fenestration is irradiated by sunshine, the glazing material generally becomes hotter than the air at its indoor and outdoor surfaces. Heat then flows by radiation and convection from the outer surface to the atmosphere and the surrounding environment, and from the inner surface to the room air and interior surfaces (Figure 9). The rate of heat flow inward [23] by radiation and convection from an unshaded single glazing is given by:

$$q_{RCi} = N_i \alpha I_t + U(t_o - t_i) \tag{24}$$

where

$$N_i = U/h_o \tag{25}$$

Therefore, the equation of heat flow becomes

$$q_{RCi} = U\left(\frac{\alpha I_t}{h_o} + t_o - t_i\right) \tag{26}$$

The equation of heat flow for double-glazed unit is similar except that two sheets of glass are considered. The heat flow may be obtained by [3]:

$$q_{RCi} = N_{io} \times \begin{pmatrix}\text{absorbed}\\\text{solar}\\\text{radiation}\\\text{outdoor}\\\text{glass}\end{pmatrix} + N_{ii} \times \begin{pmatrix}\text{absorbed}\\\text{solar}\\\text{radiation}\\\text{indoor}\\\text{glass}\end{pmatrix} + U(t_o - t_i)$$

where

$$N_{io} = U\frac{1}{h_o} \tag{27}$$

$$N_{ii} = U\left(\frac{1}{h_o} + \frac{1}{h_s}\right) \tag{28}$$

Therefore,

$$q_{RCi} = \frac{U}{h_o}\alpha I_o + U\left(\frac{1}{h_o} + \frac{1}{h_s}\right)\alpha I_i + U(t_o - t_i)$$

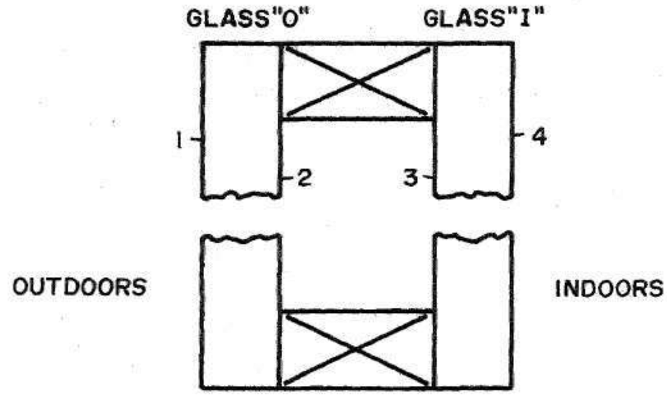


FIGURE 9 DESIGNATION OF GLASSES FOR DOUBLE-GLAZED UNITS

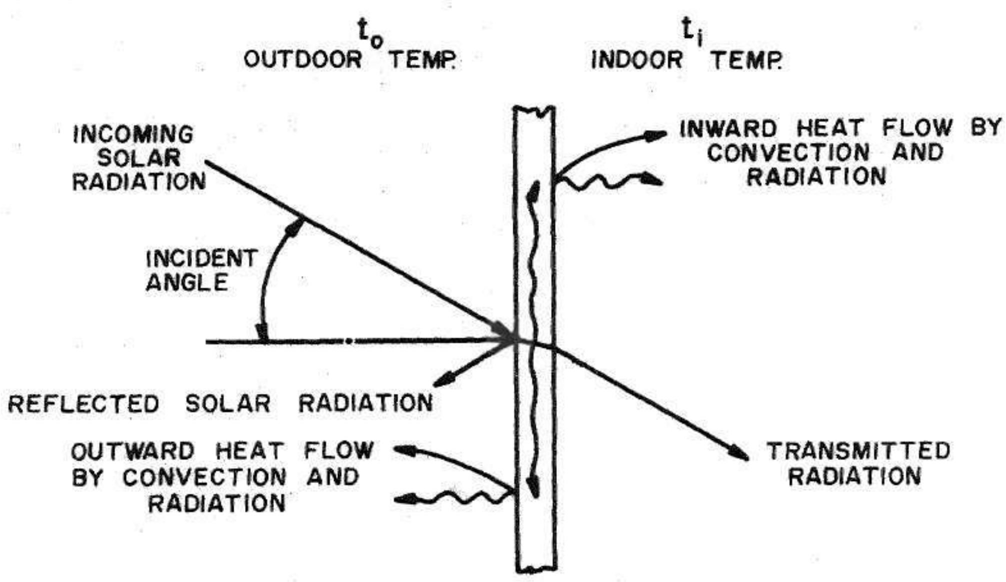


FIGURE 10 INSTANTANEOUS HEAT BALANCE FOR SUNLIT GLAZING MATERIAL

$$q_{RCi} = U[\frac{\alpha I_o}{h_o} + (\frac{1}{h_o} + \frac{1}{h_s})\alpha I_i + t_o - t_i] \tag{29}$$

The absorbed solar radiation will be different for each pane of glass, and each is calculated independently.

In Figure 9 the designation for the glasses and their surfaces are shown. The outdoor glass is denoted by an "0" in the subscript, and the indoor glass is denoted by subscript "i". Glass surfaces, starting with the outdoor surface, are numbered 1 through 4.

Absorption for the glasses in the double glazed position are:

$$\alpha_o = \alpha_1 + \alpha_2 \; (\frac{\tau_o \rho_3}{1 - \rho_2 \rho_3}) \tag{30}$$

$$\alpha_i = \alpha_3 \; (\frac{\tau_o}{1 - \rho_2 \rho_3}) \tag{31}$$

The solar radiation absorbed by the outdoor glass may be obtained from the relationship

$$\alpha I_o = I_t \alpha_o \tag{32}$$

and similarly, the radiation absorbed by indoor glass is given by

$$\alpha I_i = I_t \alpha_i \tag{33}$$

The above equations (30 through 33) apply for direct and diffuse radiation for all types of glass, including those coated with highly reflective films. The equation (29) may be written as

$$q_{RCi} = U[\frac{\alpha_o I_t}{h_o} + (\frac{1}{h_o} + \frac{1}{h_s})\alpha_i I_t + t_o - t_i)] \tag{34}$$

The characteristic for uncoated glass will be identical for both surfaces. Therefore,

$$\begin{aligned} \alpha_1 &= \alpha_2,\ \alpha_3 = \alpha_4 \\ \rho_1 &= \rho_2,\ \rho_3 = \rho_4 \end{aligned} \tag{35}$$

The inward radiation and convection gain for a double-glazed unit is given by:

$$q_{RCi} = U(\frac{\alpha I_o}{h_o} + \alpha I_i(\frac{1}{h_o} + \frac{1}{h_s}) + t_o - t_i) \tag{36}$$

$$q_{RCi} = U(\frac{I_t \alpha_o}{h_o} + I_t \alpha_i(\frac{1}{h_o} + \frac{1}{h_s}) + t_o - t_i) \tag{37}$$

a. Fenestration Heat Balance

At any instant, the heat balance between a unit area of sunlit single glazing material and its thermal environment, as shown in Figure 10, is given by [21]:

$$I_t + U(t_o - t_i) = q_R + q_s + q_t + q_{RCi} + q_{RCo} \tag{38}$$

In general, the value of q_s is relatively small, and so it is disregarded. The rate of heat rejection to the atmosphere is the sum of the reflected heat, q_R, and the outward radiation-convection heat flux, q_{RCo}.

The total instantaneous rate of heat gain through the glazing material may be expressed by:

Total instantaneous heat gain through glass		Radiation transmitted through glass		Heat flow inward by radiation-convection from inner glass surface
	=		+	

$$q_A = I_D\tau_D + I_d\tau_d + q_{RCi} \tag{39}$$

The total solar energy may be written as:

Total solar energy through glass		Radiation transmitted through glass		Inward flow of absorbed solar radiation		Heat flow due to outdoor-indoor temperature difference
	=		+		+	

For single glazing glass, the total solar energy is given by:

$$q_A = I_t\tau + N_i(I_t\alpha) + U(t_o - t_i) \tag{40}$$

For double glazing, the transmitted radiation through both glasses can be calculated by [3]:

$$q_A = I_t\bar{\tau} + N_{io}(\alpha I_o) + N_{ii}(\alpha I_i) + U(t_o - t_i) \tag{41}$$

$$\bar{\tau} = \frac{\tau_o - \tau_i}{1 - \rho_2\rho_3} \tag{42}$$

Since the first two terms of equation (40) are related to the incident solar radiation, while the third term occurs whether or not the sun is shining, therefore, equations (40) and (41) may be simplified:

Total heat admitted through glass	=	Solar heat gain	+	Conduction heat gain

Both equations may be written as:

$$q_A = FI_t + U(t_o - t_i) \tag{43}$$

The solar heat gain coefficient F is a characteristic of each type of fenestration and varies with the incident angle, since transmittance and absorptance of the glazing material are dependent upon θ. For single glazing:

$$F = \bar{\tau} + \frac{U\alpha}{h_o} \tag{44}$$

For double glazing:

$$F = \bar{\tau} + \frac{U\alpha_o}{h_o} + ((U/h_o) + U/h_s))\alpha_i \tag{45}$$

b. Solar Heat Gain Factors and Shading Coefficients

The Shading Coefficient (SC) is defined [3,20] as the ratio of the solar heat gain through a glazing system under a specific set of conditions to the solar heat gain through a single sheet of double-strength sheet glass under the same conditions. Each type of fenestration has a unique characteristic and is represented by the equation:

$$SC = \frac{\text{Solar Heat Gain of Fenestration}}{\text{Solar Heat Gain of Double-Strength Glass}} \tag{46}$$

In terms of the Solar Heat Gain Coefficient (F), the Shading Coefficient (SC) is a ratio of F for the fenestration and F for DSA glass (0.87 for standard summer conditions).

$$\begin{aligned} SC &= \frac{\text{F of fenestration}}{\text{F of DSA}} = \frac{\text{F of fenestration}}{0.87} \\ SC &= 1.15 \text{ (F of fenestration)} \end{aligned} \tag{47}$$

The Solar Heat Gain Factors (SHGF) given in ASHRAE is the heat gain through sunlit double-strength sheet glass. The values of this quantity have been calculated for the daylight hours of the 21st day of each month and are primarily for designers who do not use a digital computer for evaluating cooling loads. If a computer is used, it is more convenient to have the equations and data that were used in evaluating the tables rather than the factors themselves [3]. The computer can then be programmed to the solar heat gain for the particular circumstances. In general, the Solar Heat Gain Factor is given by:

$$\begin{matrix}\text{Solar Heat} \\ \text{Gain Factor}\end{matrix} = \begin{matrix}\text{transmitted} \\ \text{component}\end{matrix} + N_i \begin{pmatrix}\text{absorbed} \\ \text{component}\end{pmatrix} \tag{48}$$

$$\begin{matrix}\text{transmitted} \\ \text{component}\end{matrix} = I_D \sum_{j=o}^{5} t_j \cos j\theta + 2I_d \sum_{j=o}^{5} \frac{t_j}{j+2} \tag{49}$$

$$\begin{matrix}\text{absorbed} \\ \text{component}\end{matrix} = I_D \sum_{j=o}^{5} a_j \cos j\theta + 2I_d \sum_{j=o}^{5} \frac{a_j}{j+2} \tag{50}$$

where a_j and t_j are the coefficients of transmittance and absorptance for regular double-strength glass, listed in Table 4. Thus

$$\begin{matrix}\text{Solar Heat} \\ \text{Gain Factor}\end{matrix} = I_D \left(\sum_{j=o}^{5} t_j \cos j\theta + N_i \sum_{j=o}^{5} a_j \cos j\theta\right) + 2I_d \left(\sum_{j=o}^{5} \frac{t_j}{j+2} + N_i \sum_{j=o}^{5} \frac{a_j}{j+2}\right) \tag{51}$$

The values of a_j and t_j for double-strength sheet glass are given in Table 4. For other types of glass, these values may be obtained from the manufacturer of the glass.

Table 4. Coefficients for Regular Double-Strength Sheet Glass for Use in Computer Calculation of Transmittance and Absorptance

i	a_j	t_j
0	0.01154	-0.00885
1	0.77674	2.71235
2	-3.94657	-0.62062
3	8.57881	-7.07329
4	-8.38135	9.75995
5	3.01188	-3.84922

The Solar Heat Gain Factors obtained do not represent the maximum values that can occur, but are representative of conditions on average cloudless days.

For any glazing material or fenestration other than double-strength sheet glass, the Solar Heat Gain will be:

$$\text{Solar Heat Gain} = \begin{array}{c}\text{Shading}\\ \text{Coefficient, SC}\\ \text{for fenestration}\end{array} \times \begin{array}{l}\text{Solar Heat Gain Factor}\\ \text{for given orientation and}\\ \text{existing condition}\end{array} \quad (52)$$

The total instantaneous heat gain in Btu/hr-ft^2 will be:

$$q_A = (SC)(SHGF) + U(t_o - t_i) \tag{53}$$

Equation (53) is applicable at any time of the year. In winter, when the outdoor temperature is lower than the indoor temperature, the conduction heat flow which would occur in the absence of sunshine is negative or outward. In summer, the conduction heat flow is usually inward.

2. Heat Gain by Conduction Through Exterior Walls and Roofs (Transfer Function Method)

a. Sol-Air Temperature. The sol-air temperature is that temperature of the outdoor air which, in the absence of all radiation exchanges, would give the same rate of heat entry into the surface as would exist with the actual combination of incident solar radiation, radiant energy exchange with the sky and other outdoor surroundings, and convective heat exchange with the outdoor air [3,20]. The heat flux into the surface at a sunlit surface, q/A, is given by:

$$q/A = \alpha I_t + h_o(t_o - t_s) - \varepsilon \Delta R \tag{54}$$

In terms of the sol-air temperature, t_e

$$q/A = h_o(t_e - t_s) \tag{55}$$

therefore,

$$h_o(t_e - t_s) = \alpha I_t + h_o(t_o - t_s) - \varepsilon \Delta R \tag{56}$$

thus, the value of sol-air temperature (t_e) is given by:

$$t_e = t_o + \alpha I_t/h_o - \varepsilon \Delta R/h_o \tag{57}$$

Vertical surfaces receive radiation from the ground and surrounding buildings as well as from the sky; therefore, it is difficult to determine an accurate value of ΔR for them. When the solar radiation intensity is high, the surfaces of terrestrial objects are usually at a higher temperature than the outdoor air temperature, so the longwave radiation from these surfaces compensates to some extent for the low emittance of the sky [3]. For this reason, it is common practice to assume that for vertical surfaces:

$$\Delta R = 0$$

hence,

$$\varepsilon \Delta R/h_o = 0 \tag{58}$$

The value of the sol-air temperature for vertical surfaces is given by:

$$t_e = t_o + \frac{\alpha I_t}{h_o} \tag{59}$$

Horizontal surfaces receive longwave radiation only from the sky [21]. An appropriate value of ΔR is about 20 Btu, so that if $\varepsilon \simeq 1$ and $h_o \simeq 3.0$, the longwave is about -7°F [3,20]. Therefore, the value of the sol-air temperature for horizontal surfaces is given by:

$$t_e = t_o + \frac{\alpha I_t}{h_o} - 7 \tag{60}$$

Values of sol-air temperature may be calculated for two values of the parameter $\frac{\alpha}{h_o}$ in the equation of the sol-air temperature. These values may be specified as 0.15 for a light-colored surface, and 0.3 for a dark-colored surface (0.3 represents the maximum value for this parameter that is likely to occur) [3].

The value of I_t is approximately given by:

$$I_t = 1.15\ (\mathrm{SHGF}) \tag{61}$$

where the factor 1.15 is the solar energy that is excluded by a single sheet of ordinary window glass.

By substituting the values of α/h_o and I_t, we may obtain a set of two equations (vertical and horizontal surfaces) for two different values of α/h_o which specify the light or dark-colored surfaces.

(1) For light-colored surfaces ($\frac{\alpha}{h_o} = 0.15$), the sol-air temperatures for vertical and horizontal surfaces,

respectively, are given by:

$$t_{ev} = t_o + .1725 \text{ (SHGF)} \tag{62}$$

$$t_{eh} = t_o + .1725 \text{ (SHGF) } -7 \tag{63}$$

(2) For dark-colored surfaces ($\frac{\alpha}{h_o}$ = 0.30), the sol-air temperatures for vertical and horizontal surfaces, respectively, are given by:

$$t_{ev} = t_o + .345 \text{ (SHGF)} \tag{64}$$

$$t_{eh} = t_o + .345 \text{ (SHGF)} -7 \tag{65}$$

b. Heat Gain Through Exterior Walls and Roofs (Transfer Function Method). The growing concern about energy consumption and the consequent urge to analyze more thoroughly the design of alternative systems for the heating and cooling of buildings have led to a demand for improved methods of predicting the performance of air-conditioning systems. This new method has been designated as the transfer function method [3] because it utilizes the transfer function concept to relate cooling load to heat gain and heat extraction rate to cooling load and room air temperature.

A transfer function is a set of coefficients that relate an output function at some specific time to the value of one or more driving functions at that time and to previous values of both the input and output functions.

The heat gain through a wall or roof is given by:

$$q_{e,\tau} = A\left(\sum_{n=o} b_n (t_{e,\tau-n\Delta}) - \sum_{n=1} d_n \left(\frac{q_{e,\tau-n\Delta}}{A}\right) - t_{rc} \sum_{n=o} C_n\right) \tag{66}$$

Equation (66) is used to calculate the heat flow through building components. It is carried out using sol-air temperature to represent outdoor conditions, and an assumed constant indoor air temperature. It also is assumed that both indoor and outdoor surface heat transfer coefficients are constant [22]. The transfer function coefficients b and d we well as U value and $\sum_{n=o} C_n$, are listed in Tables 39 and 40, ASHRAE Handbook, pp. 426-430 [3] for various wall and roof constructions.

3. Heat Gain Through Interior Partitions, Ceilings, and Floors (Transfer Function Method)

Whenever a conditioned space is adjacent to another space in which a different temperature prevails, the transfer of heat through the partition must be considered. Calculations of this heat gain are made by use of the following equation:

$$q_{p,r} = A(\sum_{n=o} b_n(t_{b,r-n\Delta}) - \sum_{n=1} d_n(\frac{q_{p,r-n\Delta}}{A}) - t_{rc}\sum_{n=o} C_n) \quad (67)$$

Equation (67) is similar to equation (66) and is used to calculate the heat gain when the adjacent space temperature t_b is variable. When t_b is constant, or at least the variation of t_b is small compared to the difference $(t_b - t_{rc})$, the heat gain through interior partitions of the room, $q_{p,r}$ is given by the simple steady-state expression [3]:

$$q_{p,r} = UA(t_b - t_{rc}) \quad (68)$$

The transfer function coefficients b, d, U, and $\sum_{n=o} C_n$ are listed in Table 43, ASHRAE Handbook, pp. 432-433 [3].

The same simple expression gives the mean values for $q_{p,r}$ when a mean value of t_b is used even though t_b varies about this mean value. When $q_{p,r}$ is relatively small compared to the other room heat gain components, it is quite adequate to take it as being constant at its mean value. Temperature in the adjacent space should be calculated if this component of heat gain is large.

The temperature t_b may have any value over a considerable range, according to conditions in the adjacent space. It is recommended that actual temperatures be measured in adjoining spaces wherever practicable. Where nothing is known except that the adjacent space is of conventional construction and contains no heat sources, it is recommended that the difference (t_b-t_{rc}) be taken as the difference between the outdoor air and conditioned space design dry-bulb temperatures minus 5 degrees. In some cases it may be that the air temperature in the adjacent space will correspond closely to the outdoor air temperature at all times.

For floors directly in contact with the ground, or even an underground basement that is neither ventilated nor warmed, the heat transfer may be neglected for cooling-load estimates [3].

Where air-conditioning supply and return ducts pass through unconditioned spaces, there will be a transfer of heat from these spaces to the air in the ducts, even though these ducts are well insulated. An allowance should be made for these heat gains and included in the heat estimate so that air can be supplied at a temperature low enough to offset the rise caused by this heat gain [24]. There also will be some heat gain to the air in ducts passing through conditioned spaces, and since a cooling effect is produced in the spaces through which the duct passes, this is not a loss and usually can be compensated for by adjustment of air quantities between the various spaces.

4. Heat Gain by the Heat Sources Within the Conditioned Space

a. People. The rate at which heat and moisture are given off by human beings under different states of activity are different (Table 29, Ref. [3]). In many applications these sensible and latent heat gains become a large fraction of the total load. Appreciable variations in heat-emission rates must be recognized according to the age and sex of the individual, state of activity, environmental influences, and duration of occupancy, since for short occupancy the extra heat and moisture brought in may be a significant factor.

(i) Sensible Heat Gain corresponding to the change of dry-bulb temperature (Δt) for given air flow (standard condition). Sensible heat change is approximated by the equation

$$q_s = (\text{cfm})(60)(.075)(.24 + .45\ W)\Delta t \tag{69}$$

The value of (60)(.075)(.24 + .45 W) varies with W (humidity ratio),

$W = 0$	$q_s = (\text{cfm})(1.08)\Delta t$, Btu/hr
$W = 0.01$	$q_s = (\text{cfm})(1.10)\Delta t$, Btu/hr
$W = 0.02$	$q_s = (\text{cfm})(1.12)\Delta t$, Btu/hr
$W = 0.03$	$q_s = (\text{cfm})(1.14)\Delta t$, Btu/hr

Humidity ratio of 0.01 is a common value used in many air conditioning problems.

(ii) Latent Heat Gain corresponding to the change of humidity ratio (ΔW) for given air flow (standard condition).

Latent heat gain is approximated by:

$$q_{\ell} = (\text{cfm})(60)(.075)(1076)(\Delta W) = (\text{cfm})(4840)(\Delta W) \qquad (70)$$

Where the value of 1076 is the approximate heat content of 50 percent relative humidity vapor at 75°F, less the heat content of water at 50°F (50% RH at 75°F is a common design condition for the space).

b. Lighting. The instantaneous rate of heat gain from electric lighting [25,26,27] may be calculated by:

$$q_{el} = \frac{\text{total light}}{\text{wattage}} \times \begin{matrix}\text{use}\\ \text{factor}\end{matrix} \times \begin{matrix}\text{special}\\ \text{allowance}\\ \text{factor}\end{matrix} \times 3.41 \text{ Btu/hr} \qquad (71)$$

where

Total light wattage is obtained from the ratings of all fixtures installed, both for general illumination and for display use.

The use factor is the ratio of the wattage in use, for the conditions under which the load estimate is being made, to the total installed wattage. For commercial applications such as stores, the use factor would be unity.

Special allowance factor is introduced to care for fluorescent fixtures, and for fixtures which are either ventilated or installed so that only part of their heat goes to the conditioned space. It is recommended that the special allowance factor [3] be taken as 1.20 in order to allow for power consumed in the ballast. For ventilation fixtures, recessed fixtures and the like, manufacturers or other data [36] must be sought to establish the fraction of the total wattage which may be expected to enter the conditioned space [3].

c. Power. When equipment of any sort is operated within the conditioned space by electric motors, the heat equivalent of this operation must be considered in the heat gain.

The equation for this calculation is [3]:

$$q_{em} = \frac{\text{horsepower rating}}{\text{motor efficiency}} \times \frac{\text{load}}{\text{factor}} \times 2545 \text{ Btu/hr} \qquad (72)$$

It is assumed that both the motor and the driven equipment are within the conditioned space. The load factor is merely the fraction of the rated load which is being delivered under the conditions of the cooling-load estimate.

d. Appliances. Care must be taken in a cooling-load estimate to take into account the heat gain from all appliances, electrical, gas, or steam.

The most common types of heat-producing appliances found in the conditioned area are those used for food preparation in commercial and industrial food service establishments, such as restaurants, institutions, hospitals, schools, clubs, hotels, and in-plant cafeterias.

Laboratory tests [28] have shown that appliance surfaces contribute most of the heat to commercial kitchens, and that when similar appliances doing the same cooking operation are installed under an effective hood, the cooling-load is independent of the fuel or energy employed. The tests also indicated that the heat is primarily radiant energy from the appliance surfaces and cooking utensils and that convected heat and latent heat are negligible.

A conservative estimate as to the maximum heat released into the kitchen due to the radiation is 32 percent of the maximum hourly Btu input to hooded appliances. The magnitude of this maximum hourly input can be safely estimated as 50 percent of the total nameplate or catalog input ratings because of diversity of appliance use and the effect of thermostatic controls.

Direct fuel-fired cooking appliances require more heat input than electric or steam equipment of the same type and size. In the case of gas fuel, field studies [29,30] have established an overall figure of approximately 60 percent more. The laboratory tests [28] already referred to have confirmed that where the appliances are installed under an effective hood, only radiant heat adds to the cooling load and that convected and latent heat from the cooking process and combustion products are exhausted and do not enter the kitchen. The tests also have shown that radiant heat temperature rises can be substantially reduced by shielding the fronts of cooking appliances. These reductions amounted to 59 percent with asbestos paper, 61 percent with glass panels, and 78 percent using polished aluminum shielding. A floor-slot air curtain in front of the appliances reduced the radiation temperature rise by 15 percent.

5. Heat Gain Due to Ventilation and Infiltration

a. Ventilation. The introduction of outdoor air for ventilation of conditioned spaces is necessary to dilute the odors given off by people, tobacco smoke, and other internal air contaminants.

Wide variations in the amount of ventilation requirements are due primarily to differences in the total number of people smoking. People giving off body odors will require a minimum of 5 cfm per person for satisfactory dilution [2]. It should be emphasized that minimum requirements are not necessarily adequate requirements for all psychological feelings and physiological responses. Where maximum economy in space and load is essential, as in submarines or other restricted spaces, as little as 1 cfm of outdoor air per person has been found to be sufficient, provided that satisfactory ventilation is simultaneously obtained by an adequate decontamination of recirculated air [31].

Local codes and ordiances frequently specify ventilation requirements for public places and for industrial installations. For operating rooms, minimum requirements for safe practice are given in a National Board of Fire Underwriters pamphlet

[32]. This pamphlet does not require 100 percent outdoor air in operating rooms, although 100 percent outdoor air is sometimes used. Limitation of the outdoor air to 6 to 8 changes per hour has received increasing acceptance [3,20].

Recommended and minimum ventilation rates for the most common applications are summarized in Table 5. For further general applications, a basis for estimating the cfm per person may be taken as:

(1) Nonsmokers----7-1/2 cfm recommended, 5 minimum

(2) Smokers-------40 cfm recommended, 25 minimum

The heat gain due to the introduction of outdoor air for ventilation is determined once the indoor and outdoor design conditions are fixed. The outdoor air required is primarily dependent upon the number of occupants and upon the materials and apparatus within the space which may give off odors. Consideration should be given to reducing the heat gain from outdoor air by the use of filtered, recirculated air in combination with outdoor air. Filtered, recirculated air may be supplied to the occupied zone to reduce the quantity of outdoor air, depending upon the filter efficiency for the particular contaminants. Treatment of the recirculated air to provide some form of odor control also may be used [3].

In comfort applications, where local codes permit, it is possible to reduce the capacity requirements of the installed equipment by reducing the ventilation air quantity

Table 5. Outdoor Air Requirements[a]

APPLICATION	SMOKING	cfm PER PERSON[b] RECOMMENDED	cfm PER PERSON[b] MINIMUM[c]	cfm PER SQ. FT. OF FLOOR[b] MINIMUM[c]
APARTMENT				
AVERAGE	SOME	20	10	......
DELUXE	SOME	20	10	......
BANKING SPACE	OCCASIONAL	10	7-1/2	......
BARBER SHOPS	CONSIDERABLE	15	10	......
BEAUTY PARLORS	OCCASIONAL	10	7-1/2	......
BROKERS' BOARD ROOMS	VERY HEAVY	50	20	......
COCKTAIL BARS	......	40	25	......
CORRIDORS (SUPPLY OR EXHAUST)	......	....	....	0.25
DEPARTMENT STORES	NONE	7-1/2	5	0.05
DIRECTORS' ROOMS	EXTREME	50	30	......
DRUG STORES[e]	CONSIDERABLE	10	7-1/2	......
FACTORIES[d,f]	NONE	10	7-1/2	0.10
FIVE AND TEN CENT STORES	NONE	7-1/2	5	......
FUNERAL PARLORS	NONE	10	7-1/2	......
GARAGES[d]	......	....	....	1.0
HOSPITALS				
OPERATING ROOMS[f,g]	NONE	....	....	2.0
PRIVATE ROOMS	NONE	30	25	0.33
WARDS	NONE	20	10	......
HOTEL ROOMS	HEAVY	30	25	0.33
KITCHENS				
RESTAURANT	......	....	....	4.0
RESIDENCE	......	....	....	2.0
LABORATORIES[e]	SOME	20	15	......
MEETING ROOMS	VERY HEAVY	50	30	1.25
OFFICES				
GENERAL	SOME	15	10	0.25
PRIVATE	NONE	25	15	0.25
PRIVATE	CONSIDERABLE	30	25	0.25
RESTAURANTS				
CAFETERIA[c]	CONSIDERABLE	12	10	......
DINING ROOM[c]	CONSIDERABLE	15	12	......
SCHOOLROOMS[d]	NONE	....	....	......
SHOP, RETAIL	NONE	10	7-1/2	......
THEATER[d]	NONE	7-1/2	5	......
THEATER	SOME	15	10	......
TOILETS[d] (EXHAUST)	......	....	....	2.0

a TAKEN FROM PRESENT-DAY PRACTICE.

b THIS IS CONTAMINANT-FREE AIR.

c WHEN MINIMUM IS USED, TAKE THE LARGER OF THE TWO.

d SEE LOCAL CODES WHICH MAY GOVERN.

e MAY BE GOVERNED BY EXHAUST.

f MAY BE GOVERNED BY SPECIAL SOURCES OF CONTAMINATION OR LOCAL CODES.

g ALL OUTSIDE AIR RECOMMENDED TO OVERCOME EXPLOSION HAZARD OF ANESTHETICS.

at the time of peak load. At time other than peak load, the calculated outdoor quantity is used. Scheduled ventilation is recommended only for installations operating more than 12 hours or three hours longer than occupancy, to allow some time for flushing out the building when no odors are being generated. It has been found [2], by tests, that few complaints of stuffiness are encountered when the outdoor air quantity is reduced for short periods of time, provided the flushing period is available. It is recommended [2,3, 20] that, in any case, the outdoor air quantity be reduced to no less than 40 percent of the recommended quantity.

b. Infiltration. Infiltration of air and, particularly, moisture into a conditioned space is frequently a source of sizable heat gain or loss. The quantity of infiltrated air varies according to tightness of doors and windows, porosity of the building shell, height of the building, stairwells, elevators, direction and velocity of wind, and the amount of ventilation and exhaust air. Many of these cannot be accurately evaluated and must be based on the judgment of the estimator.

Generally, infiltration may be caused by wind velocity, or stack effect, or both:

(1) Wind Velocity--The wind velocity builds up a pressure on the windward side of the building and a slight vacuum on the leeward side. The outdoor pressure build-up causes air to infiltrate through crevices in the construction

and cracks around the windows and doors. This, in turn, causes a slight build-up of pressure inside the building, resulting in an equal amount of exfiltration on the leeward side.

(2) Difference in Density or Stack Effect--The differences in temperatures produce differences in density of air between the inside and outside of the building. In tall buildings, this density difference causes summer and winter infiltration and exfiltration as follows:

Summer--Infiltration at the top and exfiltration at the bottom.

Winter--Infiltration at the bottom and exfiltration at the top.

This opposite-direction flow balances at some neutral point near the mid-height of the building. Air flow through the building openings increases proportionately from the neutral point towards the top and the bottom of the building. The infiltration from stack effect is greatly influenced by the height of the building and presence of open stairways and elevators. The combined infiltration from wind velocity and stack effect is proportional to the square root of the sum of the heads acting on it [2].

The increased air infiltration flow caused by stack effect is evaluated by converting the stack effect force to an equivalent wind velocity, and then calculating the flow from the wind velocity data in the tables.

In buildings over 100 feet tall, the equivalent wind velocity may be calculated from the following formula, assuming a temperature difference of 70°F db (winter) and a neutral point at the mid-height of the building:

$$V_e = \sqrt{V^2 - 1.75a} \quad \text{(for upper section of tall buildings--winter)} \tag{73}$$

$$V_e = \sqrt{V^2 + 1.75b} \quad \text{(for lower section of tall buildings--winter)} \tag{74}$$

where

V_e = equivalent wind velocity, mph

V = wind velocity normally calculated for location, mph.

a = distance window is above mid-height, feet.

b = distance window is below mid-height, feet.

(i) Infiltration Through Windows and Doors [33], Summer. Infiltration during the summer is caused primarily by the wind velocity creating a pressure on the windward side. Stack effect is not normally a significant factor because the density difference is slight, (0.073 lb/cu ft at 75°F db, 50% rh and 0.070 lb/cu ft at 95°F db, 75°F wb). This small stack effect in tall buildings (over 100 feet) causes air to flow in the top and out the bottom. Therefore, the air infiltrating in the top of the building, because of the wind pressure, tends to flow down through the building and out the doors on the street level, thereby offsetting some of the infiltration through them.

In low buildings, air infiltrates through open doors on the windward side unless sufficient outdoor air is introduced through the air conditioning equipment to offset it; refer to "Offsetting Infiltration with Outdoor Air."

With doors on opposite walls, the infiltration can be considerable if the two are open at the same time.

G. Cooling Load (Transfer Function Method)

The objective of cooling load calculations, is to estimate the maximum load that is likely to occur, which helps in the selection of equipment. Each component of the space heat gain causes the cooling load of the space to become larger. One of the ways of relating a heat gain component to the corresponding cooling load component is to use a transfer function [8,9,35] which depends on the nature of the heat gain and on the heat storage characteristic of the space (i.e., of the wall, roof, floor, etc., that enclose the space).

In this method, the heat gain ($q_{e,\tau}$) is given in the form of a time series, which is the value of the heat gain at equally-spaced points in time. The corresponding cooling load (Q_τ) at time (τ) can be related to the current value of ($q_{e,\tau}$) and the preceding values of cooling load and heat gain by:

$$Q_r = \sum_{i=1}^{n} v_{i-1}\, q_{e,r-(i-1)\Delta} - w_i\, Q_{r-i\Delta} \tag{75}$$

$$Q_r = (v_0\, q_{e,r} + v_1 q_{e,r-\Delta} + v_2 q_{e,r-2\Delta} + \ldots)$$

$$-w_1 Q_{r-\Delta} - w_2 Q_{r-2\Delta} - w_3 Q_{r-3\Delta} \ldots. \tag{76}$$

where (i) is taken from 1 to the number of the heat gain components (n). The terms v_0, $v_1, \ldots$, w_1, $w_2, \ldots$, are the coefficients of the transfer function:

$$K(Z) = \frac{v_0 + v_1 z^{-1} + v_2 z^{-2} + \ldots}{1 + w_1 z^{-1} + w_2 z^{-2} + \ldots} \tag{77}$$

which relates the transfer of the corresponding parts of the cooling load and of the heat gain. The coefficients of the transfer function depend on: the size of the time interval (Δ) between successive values of the heat gain and cooling load, the nature of the heat gain (how much is in the form of radiation and where it is absorbed), and on the heat storage capacity of the room. Therefore, different transfer functions are used to convert each distinct heat gain component to cooling load.

Transfer function coefficients for three types of room construction are given in Table 44, page 434 of Ref. [3]. These transfer function coefficients are for rooms where all the input energy (i.e. heat gain) eventually appears as cooling load. In most cases, a fraction of the input is lost to the surroundings. This fraction depends on the thermal conductance between the room air and the surroundings, and an estimate of the fraction, (F_c) that appears as the cooling load can be found in Figure 11. The factor (F_c) is plotted versus the unit length conductance between room air and surroundings, (K_T) where

$$K_T = \frac{1}{L_F} (U_w A_w + U_{ow} A_{ow} + U_c A_c) \quad \text{Btu/hr-ft}^2{}^\circ\text{F} \qquad (78)$$

The transfer function coefficient for a particular load component is obtained simply by multiplying the (v) coefficients by (F_c) factor for that component.

H. Supply State of Conditioned Air

1. Sensible Load--Total Load Ratio

The total cooling load on a zone or a building depends partly on the fraction of that load which is due to the moisture gain into the enclosure (latent heat), and partly on the load which is due to the direct transfer of sensible heat which does not affect moisture content of the enclosure. The change in air temperatures due to sensible heat gain can be represented as a length in the horizontal direction on the psychrometric chart whereas the change in specific humidity of the air due to latent heat gain is represented as a length along a constant dry bulb temperature included in the

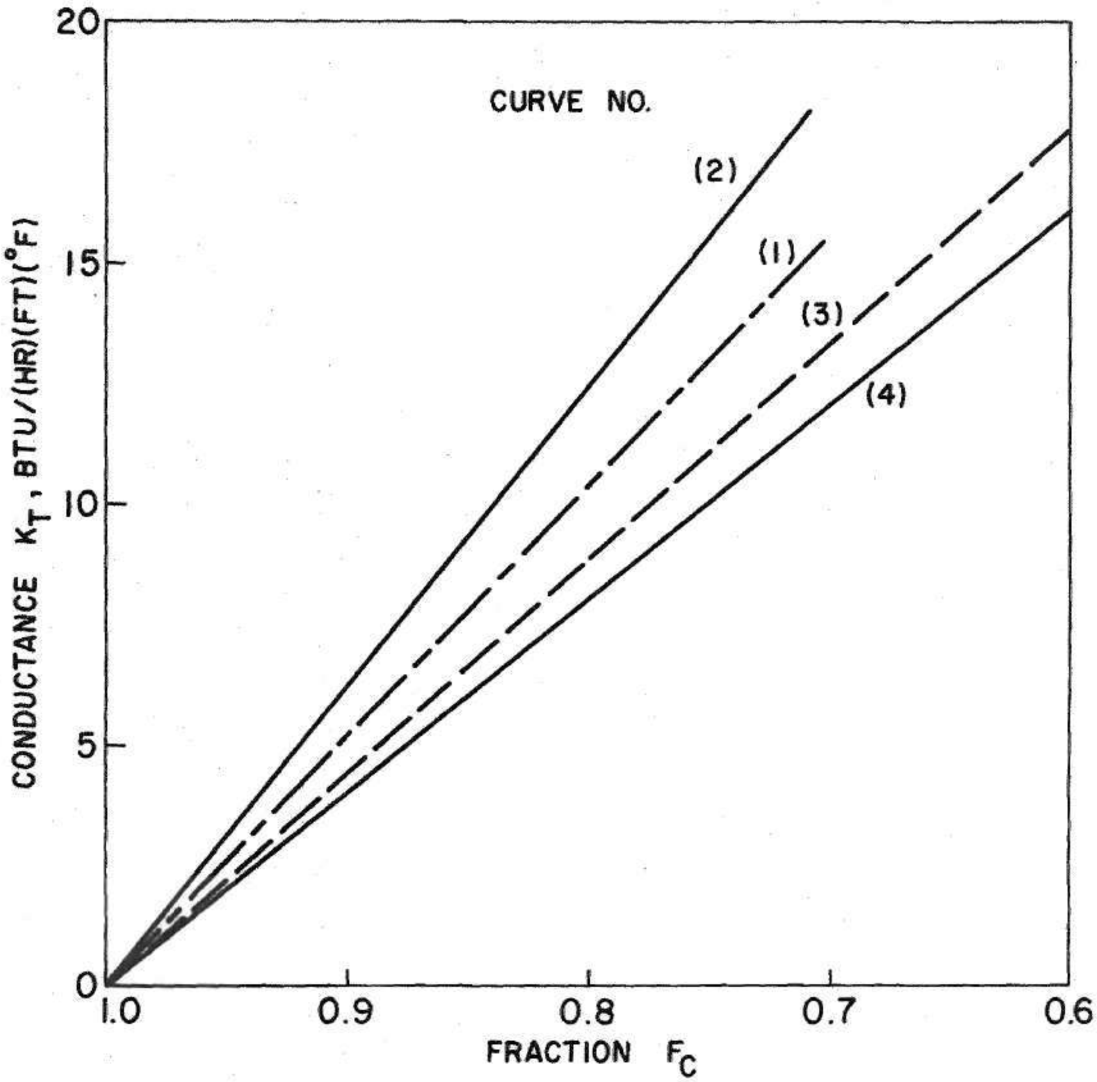


FIGURE 11

F_C FACTORS FOR VARIOUS ROOM TRANSFER FUNCTIONS chart. The ratio of sensible heat to the total heat which is defined as sensible heat factor which determines the relative position of the initial and final states of air passing from the conditioned equipment into the enclosure maintained at constant temperature and humidity. In order to maintain specified indoor conditions, it is important to supply the conditioned air such that its state lies on this sensible heat ratio line established for the particular zone.

2. Critical Loading Conditions

The variation in external climatic conditions and the usage pattern of internal space constantly influences not only the proportion of sensible and latent heat gain of a zone, but also their sum. Due to diversity among the zones with respect to these two forms of heat gain, the building sensible heat factor is different than the corresponding zonal values. These variations can be examined by using computer output. Their envelope for individual zones or the entire building will include five critical loading conditions. These are:

The sensible load is maximum

The latent load is maximum

The total load is maximum

The sensible heat ratio is maximum*

The sensible heat ratio is minimum*

---

*The theoretical range for the sensible heat ratio is between 0 and 1. For any given zone, the practical maximum and minimum will be well within this range.

These critical loading conditions have been represented in Figure 12. Here it is assumed that the zone temperature and humidity are maintained at constant value. The volume of conditioned air is assumed constant. With these assumptions the end of each of these five lines represent the state of the conditioned air that enters the zone in order to absorb its heat gain.

In Figure 12, let the direction line marked SH_{max} correspond to the sensible heat-total heat ratio when sensible heat load is a maximum. This is recognized by the maximum change in dry bulb temperature, which also determines the lowest dry bulb temperature, t_d, that will ever be required at the supply state when operating with fixed weight rate of air.

Similarly, the direction line marked TH_{max} has a slope determined by the ratio when total heat is a maximum. Taking the weight rate at the value previously determined for maximum sensible load gives a supply state for which the total enthalpy change ΔTH_{max}, has its greatest value or lowest enthalpy of supply air. The corresponding sensible heat gain is less than that in the previous case. The third critical load occurs at the condition for which latent heat gain is a maximum. For this case, the direction line is marked LH_{max}, and the supply state (for same weight rate as before) is such that the latent heat gain ΔLH_{max} is greatest of all possible situations, though neither sensible nor total

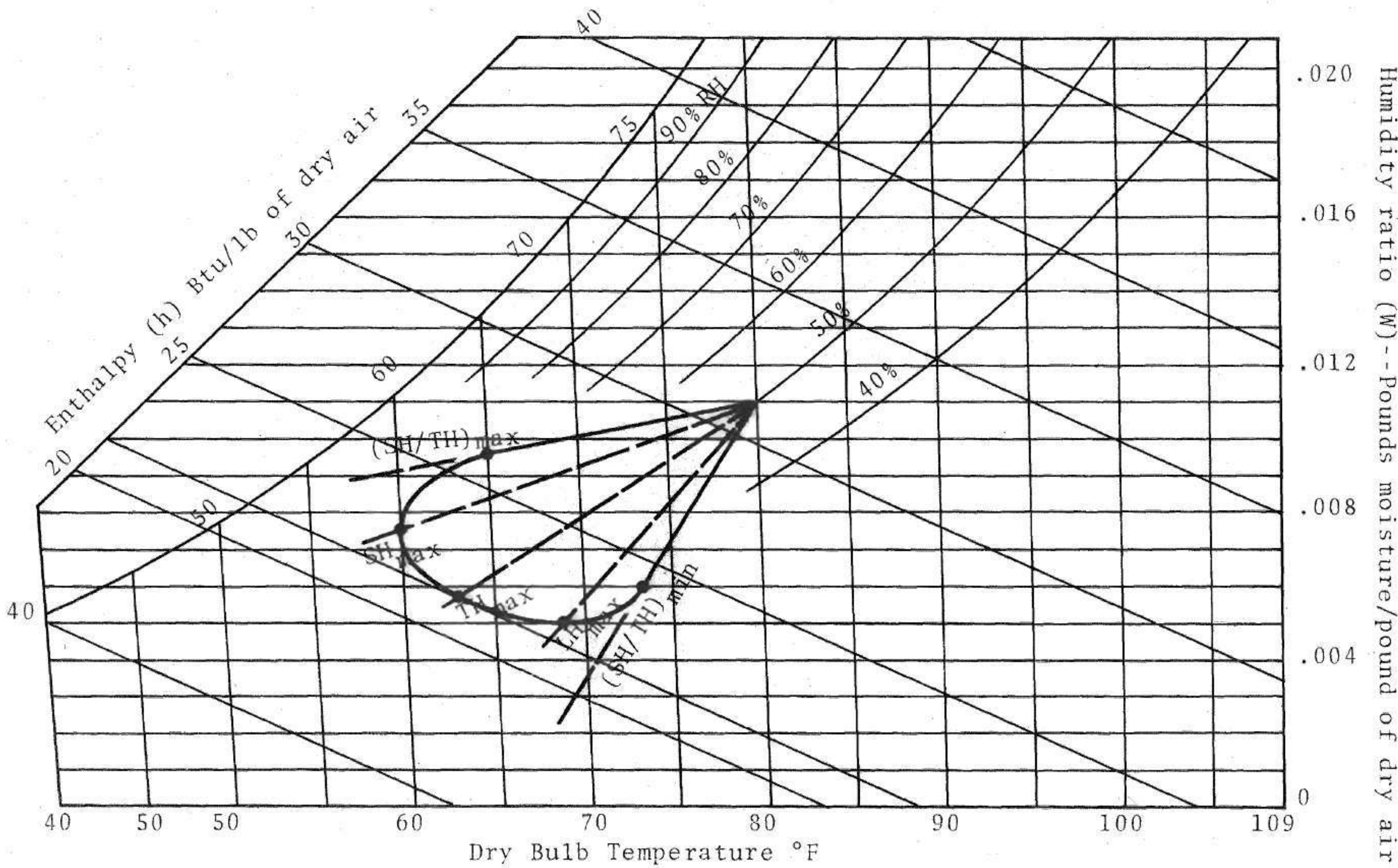


Figure 12. Five Critical Load Conditions

loads are less than the maximum established previously.

It should be noted that these five critical conditions for a given zone will occur at different times of the day and the day of the year. If one were to run the computer program repeatedly covering these zones and probable duration of the cooling season, it is possible to recognize these critical conditions by comparison of numbers or their ratios as defined by sensible heat factor.

In order to find the two remaining loading conditions which occur at partial load, consider the other two direction lines in Figure 12 in which one of them is for the maximum ratio of sensible heat-total heat and the other is for minimum ratio. The corresponding states of supply air are established for fixed weight rate. Consider the locus line already obtained to include the two extreme ratio states gives the solid curve of Figure 12 as the complete locus of all critical loading conditions which occur with constant minimum weight rate. Similarly the locus based on constant maximum weight rate can be constructed [37]. An infinite number of loci, one for each possible weight rate, fall between those for maximum and minimum. A curve through these five supply states represents a locus of states which must be produced by the system if it is to maintain the room at state r for any combination of critical loads established by the computed load profile analysis and assuming constant weight rate of air [37].

The envelope curve demonstrated in Figure 12 appears as a wedge shape and, hence, it can be termed as "load wedge." This is generated by assuming constant weight of air at all times supplying the zonal load. A large amount of computer output for the sensible, latent, and total heat gain that can be generated using this program together with comparison of these numbers and simple calculations will generate this load wedge for individual zones or the building as a whole. These are of utmost importance in the design of air distribution and air conditioning systems.

CHAPTER III

GENERAL CALCULATION PROCEDURE AND COMPUTER PROGRAMS

A. Introduction

The problem of determining the cooling load of buildings under any given condition has drawn the attention of many research and industrial organizations all over the world [36]. With the ever increasing use of digital computers in almost all branches of building science, the computational methods which were earlier considered as unmanageable are now finding wide application. This trend is more evident for the problem of the calculation of inside air temperatures and heating and cooling load of buildings which are exposed to variable weather conditions.

B. Computer Programs

In order to determine the cooling load under a given climate, a large number of factors must be taken into account as input data, and some other factors must be calculated by using some of the input data as shown in Figure 13. The input data can be conveniently grouped into three categories, and factors to be calculated may be grouped into several computer subprograms and combinations of them to form a general program for calculation of the cooling load in a

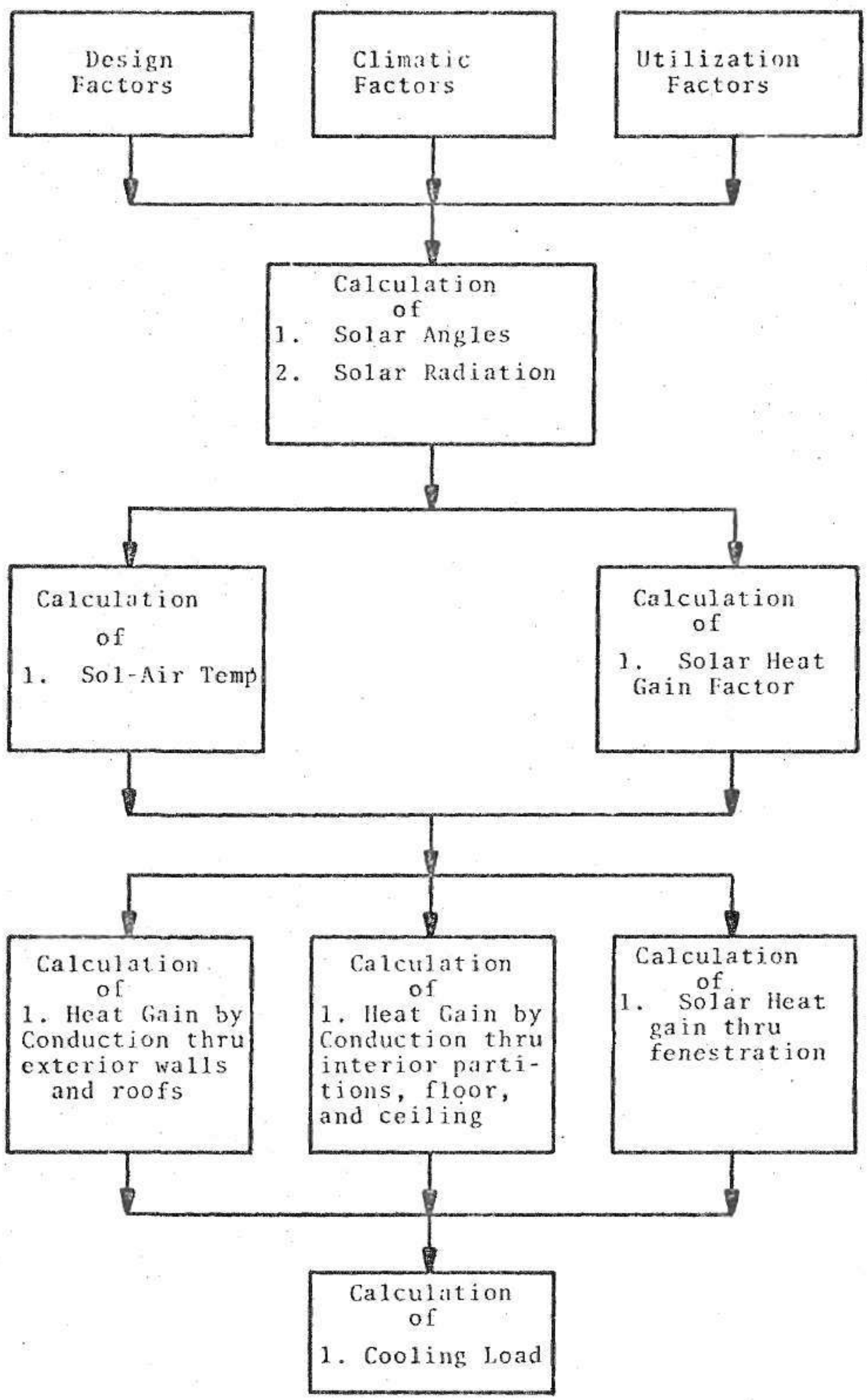


Figure 13. Schematic Diagram for Digital Computer Determination of Cooling Load

building. Subprograms are for calculation of solar angles; solar radiations; solar heat gain factors; sol-air temperatures; heat gain by conduction through exterior walls and roofs; heat gain through interior partitions, floors, and ceilings; solar heat gain through fenestrations; and cooling load. Subprograms are designed so that each may be performed independently and their output may be computed with separate input data, or they may be used as subroutines in the general program. Subroutines usually use some of the outputs of the preceding subroutines as well as some input data of the general program. Subroutine TOTINT, which is the first in the series, is the only one that uses just the input data for its computations. The main difference between the independent computer programs and subroutines beside input is the use of parameters NMAX and KKKK in independent programs which designate the choice of the user of the program for the number of calculations in a day and number of days during a year, respectively. In subroutines, there is no need for using these two parameters, because they have already been used in the main program and subroutines would be executed accordingly.

The sequential steps in the computations of independent programs, subroutines, and main programs are shown in Figures 14 through 26. The inputs and outputs of the corresponding programs are listed in Tables 6 through 12.

The method used in calculating the heat gain through the exterior walls and interior partitions, as well as the cooling load is the transfer function method. In this method, the initial values of heat gains and cooling load are assumed to be zero. The effect of this assumption becomes negligible as the calculation is repeated for successive 24-hour cycles. The minimum number of cycles that computation should be repeated is four [3]. To illustrate convergence of output as well as the use of developed computer programs in calculation of cooling load and other factors, data input for four consecutive days have been used in each independent program. The general computer program also has been applied to calculate the cooling load of a general office building. Calculation of this program also has been done for four consecutive days. Input and output, as well as the computer program printout of individual programs, are in Appendix A. For each case, hand calculations have been made for one hour or more in a day to check the values obtained in computer program output. These illustrations are in Appendix C.

C. Input Data

1. Design Factors

a. Thermal characteristics of building sections, walls, roof, ceiling, floor, doors, partitions.

b. Surface radiation characteristics (absorptivity, emissivity, reflectivity and transmitivity of building surfaces.

c. Shape and orientation of the building and internal layout.

d. Window design, number, location and type of glass areas.

e. External and internal shading devices, such as overhangs, louvers and venetian blinds, curtains.

2. Climatic Factors

a. Solar radiation (direct and diffuse).

b. Daily temperature variation.

c. Wind velocity and direction.

d. Humidity.

3. Utilization Factors

a. Ventilation.

b. Internal heat sources and sinks.

c. Occupancy density.

d. Living habits which influence functional use.

The complexity of the problem increases not only because of the large number of variables that come into the picture, but also because of the interactions between them.

D. Subprograms

1. Solar Angles and Solar Radiations

This computer program is capable of computing the solar angles and solar radiation impinging on a particular plane with any slope from zero to 90 degrees, at any point on the earth for all hours in a day and any number of days in a year. This may be done by simply changing the values of parameters NMAX and KKKK, respectively. In doing this, data cards should be changed accordingly.

The computer program starts the operation by reading the input, and then calculates the values of the declination angle, sunrise time, sunset time, and the number of possible hours of sunshine.

Before sunrise and after sunset, values of solar radiations (direct and diffuse) are zero. These values may be obtained by using the negative values of altitudes which have been calculated. The negative values of the altitude at night indicated that the position of the sun relative to the point Q on the earth is below the horizon and the angle between the sun's rays and their projection on the horizon in a vertical plane is negative (Figure 7). Therefore, there is no solar radiation at point Q; however, there might be some diffuse radiation just before sunrise and right after sunset with negligible effect on the calculation.

This computer program in the form of a subroutine is called "subroutine TOTINT."

2. Solar Heat Gain Factor

In this computer program, the Solar Heat Gain Factor has been calculated for eight different orientations and for the horizontal surface. These orientations comprise surfaces facing north, northeast, east, southeast, south, southwest, west, and northwest.

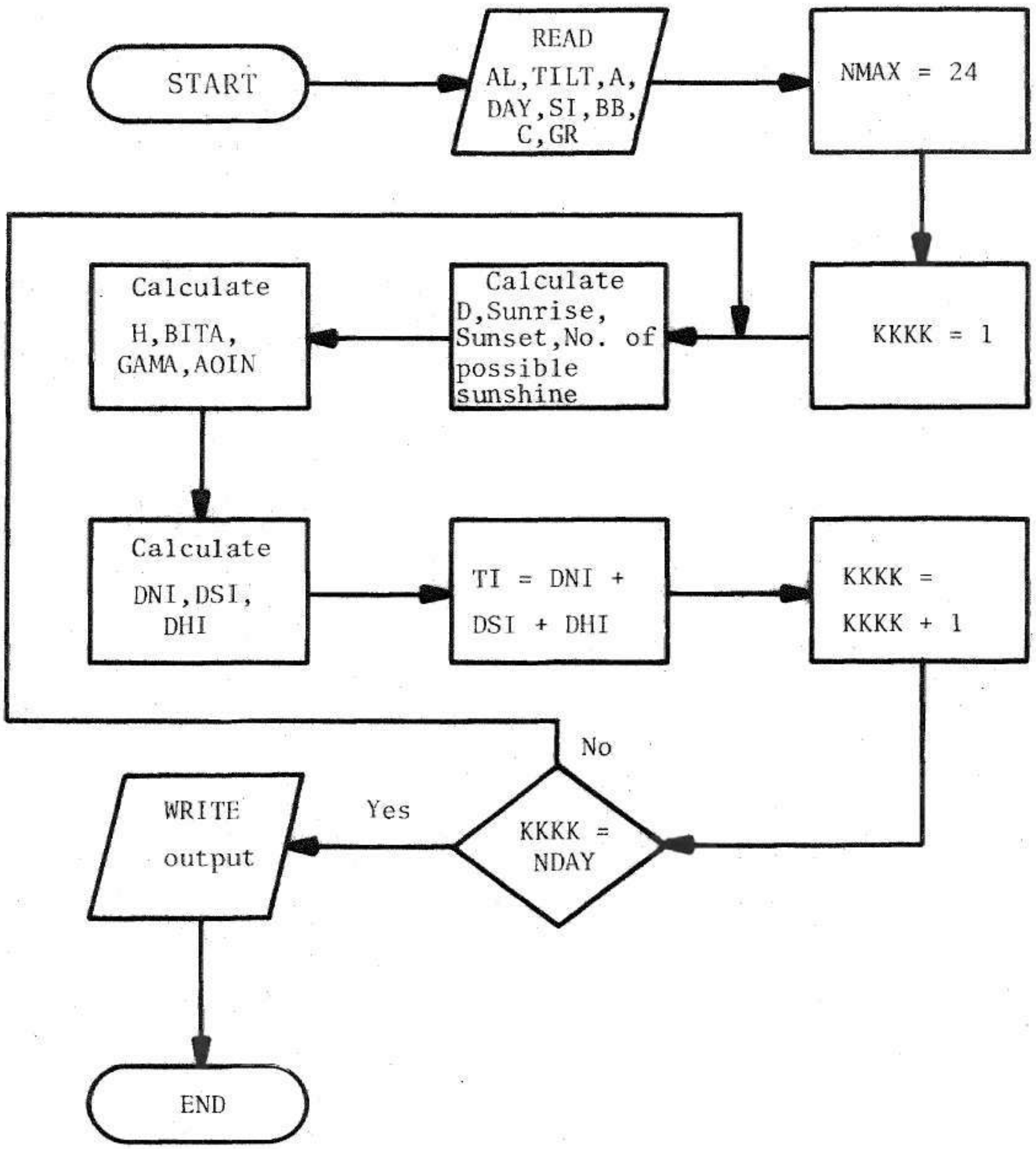


Figure 14. Flow Diagram for Calculation of the Solar Angles and Solar Radiation as an Independent Program

Table 6. Input and Output of the Computer Program for Calculation of the Solar Angles and Solar Radiations

No.	Input	No.	Output	No.	Output
1	AL	1	TILT	7	H(I)
2	TILT	2	D	8	BITA(I)
3	A	3	Sunrise	9	GAMA(I)
4	DAY	4	Sunset	10	AOIN(I)
5	SI	5	Number of possible hours of sunshine	11	DNI(I)
6	BB			12	DSI(I)
7	C			13	TI(I)
8	GR	6	Azimuthal angle for sunrise and sunset		
9	ST(I)				

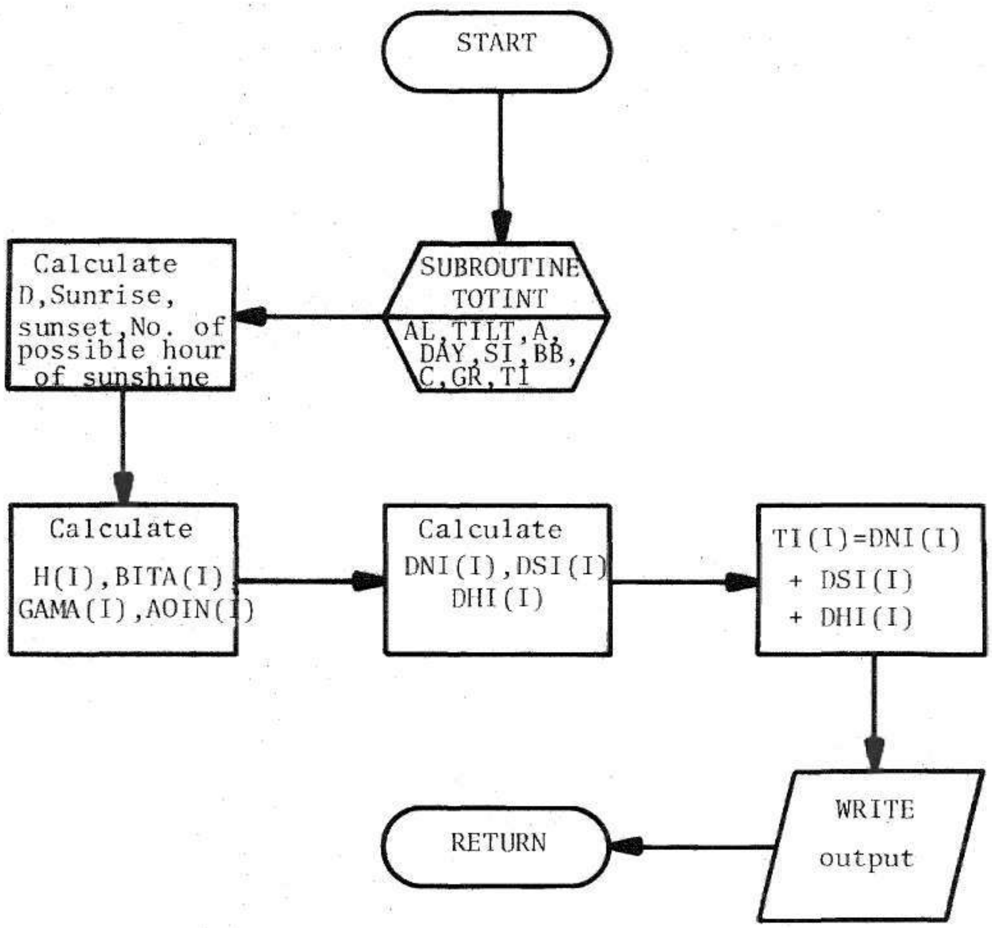


Figure 15. Flow Diagram for Calculation of the Solar Angles and Solar Radiation as a Subroutine

Table 7. Input and Output of the Computer Program for Calculation of the Solar Heat Gain Factors

No.	Input	No.	Output
1	T(I)	1	AL
2	AA(I)	2	D
3	DAY	3	DNI(I)
4	AL	4	BITA(I)
5	GR	5	SHGF(N,I)
6	A		
7	B		
8	C		
9	BL(I)		
10	BM(I)		
11	BN(I)		

If in calculations of the solar heat gain factor, not all of the above nine orientations are needed, then the desired orientations may be chosen by setting the values of NWALL to the desired sequence values of orientations. The values for this sequence are from 1 to 9, corresponding to the eight orientations above and the horizontal surface, respectively. Calculations for orientations other than those above may be done by using the proper value of the wall-solar azimuth as mentioned in equations 8 and 9 in the previous chapter.

The value of the solar heat gain factor is directly proportional to the values of the solar radiation and the orientation of the surface. The maximum value of this factor is different for different orientations, depending on the time of the day and day of the year. The value of this factor is zero in the absence of solar radiation. This computer program is capable of computing the solar heat gain factor at any time of the day, depending on the number of possible hours of sunshine and ignoring the zero values.

3. Heat Gain by Conduction Through the Exterior Walls and Roof

This computer program computes and prints the results of the sol-air temperature and the heat gain calculation. In the first output, the sol-air temperatures are calculated for nine orientations each day for 24 hours a day. The values of the sol-air temperature are directly proportional

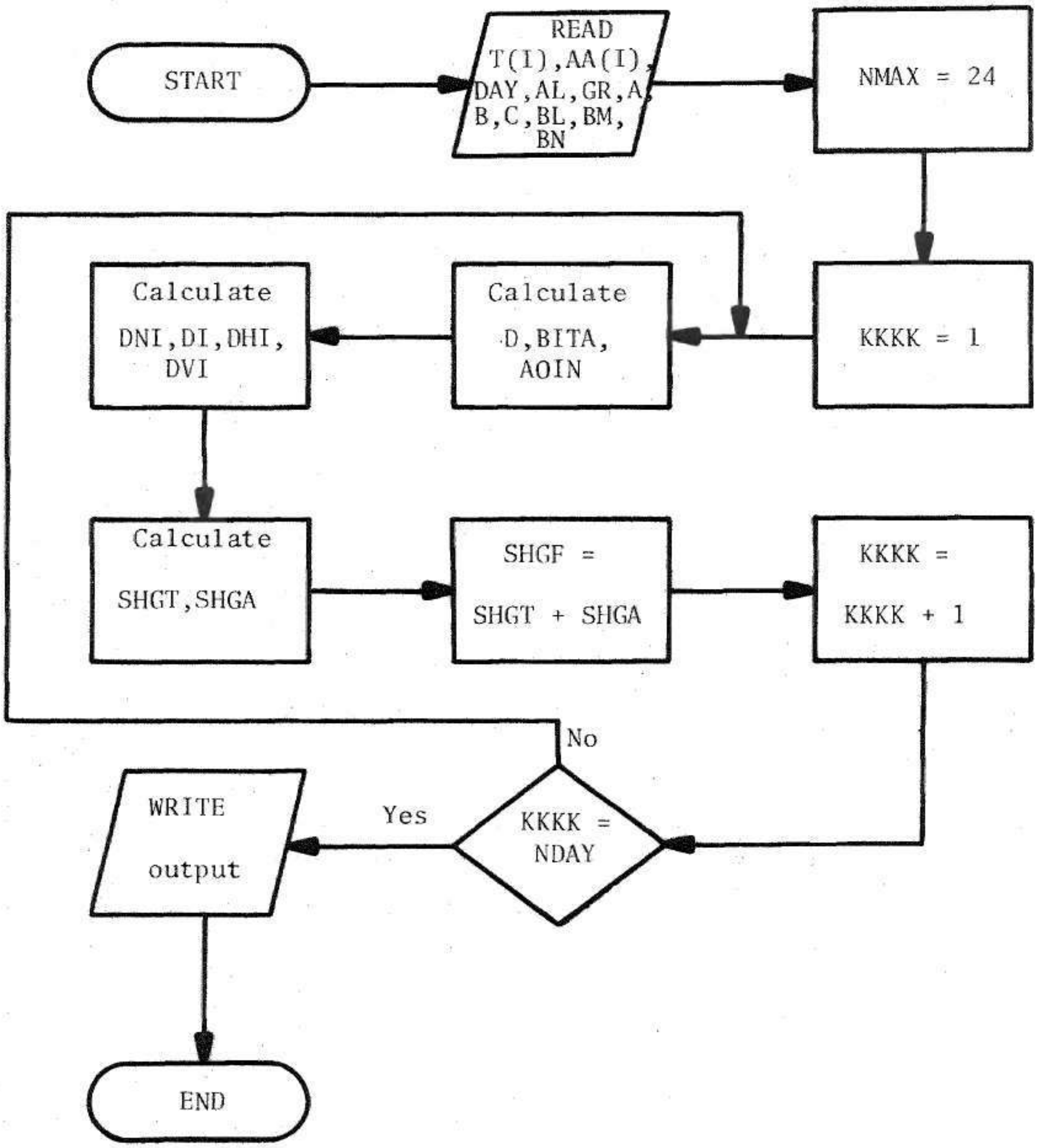


Figure 16. Flow Diagram for Calculation of the Solar Heat Gain Factors as an Independent Program

Table 8. Input and Output of the Computer Program for Calculation of the Heat Gain by Exterior Walls and Roofs

No.	Input	No.	Output
1	A(I)	1	TSAI(I,J)
2	DO(I)	2	QE
3	BO(I)		
4	CO(I)		
5	SHGF(I,J)		
6	TO(J)		

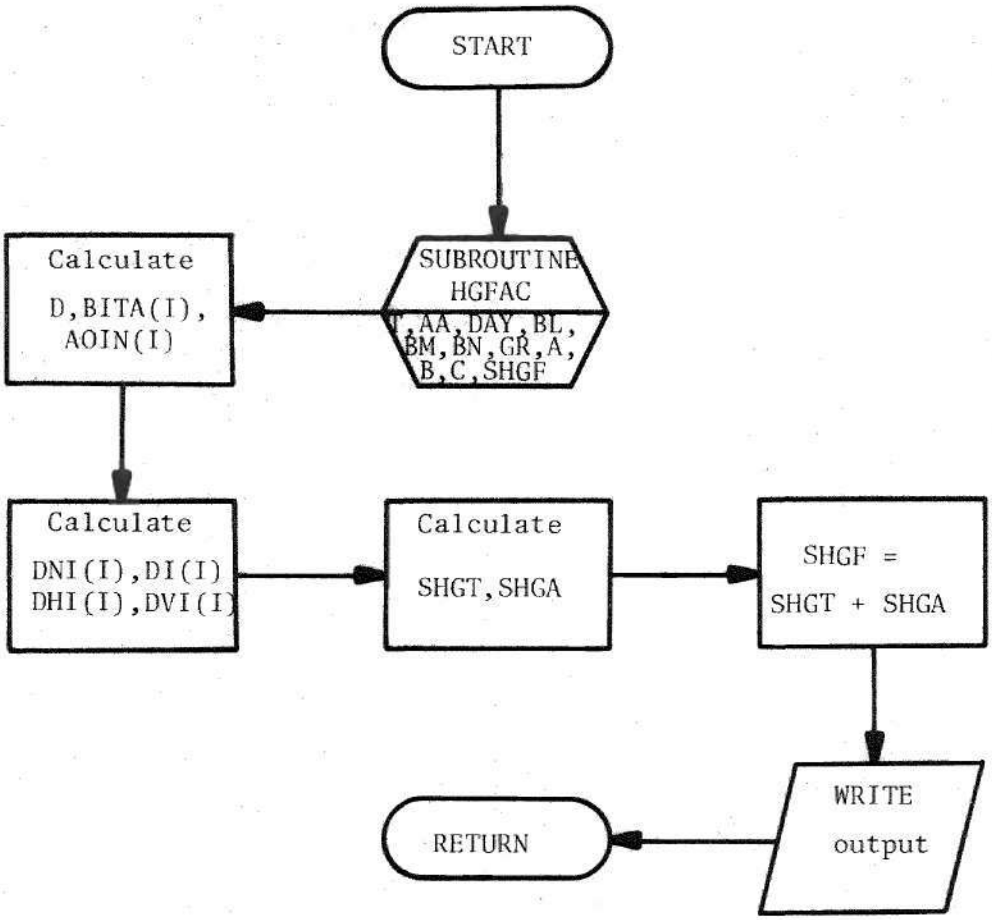


Figure 17. Flow Diagram for Calculation of the Solar Heat Gain Factors as a Subroutine

to the values of the solar heat gain factors. In each orientation, this value is maximum when the solar heat gain factor is maximum, and is minimum when the factor is minimum.

The calculation of the heat gain for a particular time requires information on the values of the sol-air temperature both at that and the preceding time, as well as the heat flow at the preceding time. Initially, the "history" of the heat flow is unknown, but it can be assumed to be zero to start the calculations. The effect of this assumption on the calculated heat flow values becomes negligible as the calculation is repeated for successive 24-hour cycles.

The heat flow also has been calculated for the nine orientations each day for 24-hours a day. In this computer program, the nine orientations are numbered as wall numbers 1 through 9 and desired orientations may be chosen similar to the procedure of the solar heat gain factor subprogram.

4. Heat Gain by Conduction Through the Interior Partitions, Floors and Ceilings

Three different cases must be considered in calculating the heat gains of the interior partitions, depending on whether the variation of the air temperature of the adjacent space is relatively large, small, or even if it has a constant air temperature. For the cases where the variation of the air temperature is small or the adjacent space's air temperature is constant, the calculation can be done by a simple equation, as mentioned in the previous chapter

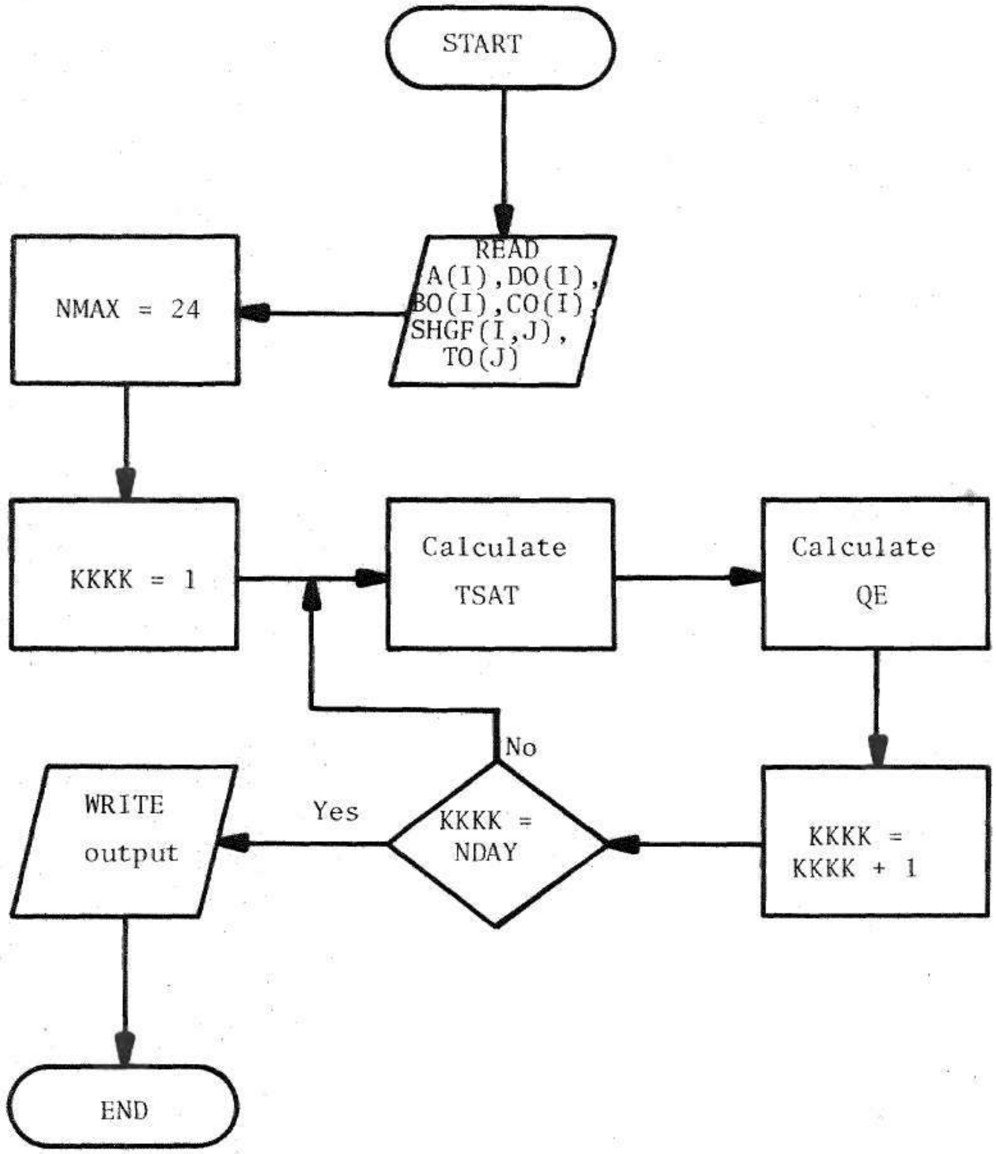


Figure 18. Flow Diagram for Calculation of the Sol-Air Temperatures and the Heat Gain Through the Exterior Walls and Roofs as an Independent Program

Table 9. Input and Output of the Computer Program for Calculation of the Heat Gain by Interior Walls and Partitions

No.	Input	No.	Output
1	TB(I,J)	1	QWZ
2	A(I)		
3	DX(I)		
4	BX(I)		
5	CX(I)		

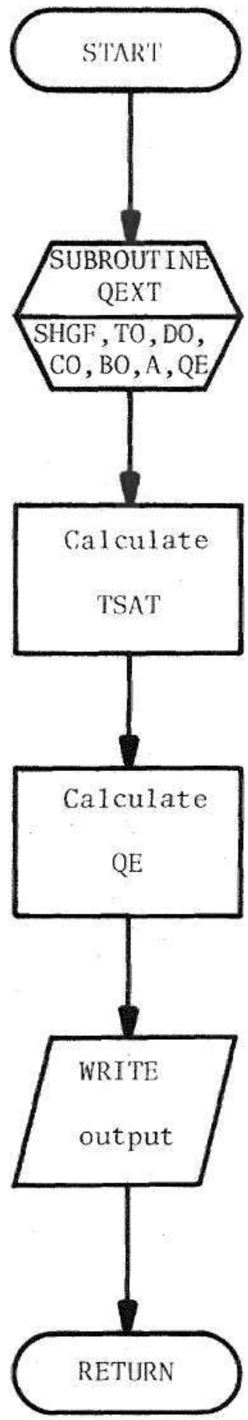


Figure 19. Flow Diagram for Calculation of the Sol-Air Temperatures and the Heat Gain Through the Exterior Walls and Roofs as a Subroutine

(equation 68). But if the air temperature of the adjacent space has a large variation, the computation is slightly more complicated. This computer program has been developed in a manner outlined in the previous section (calculation of the exterior wall heat gain). In this computer program, the sol-air temperatures have been calculated, but have not been printed out.

In calculation of the heat gain as before, a zero value for the initial heat flow has been assumed to start the calculations. The heat flow in this computer program also has been calculated for nine orientations which have been numbered from 1 through 9, and choice of orientations has been made in the same manner as in the solar heat gain factor subprogram.

5. Solar Heat Gain Through the Fenestrations

The amount of solar heat gain through windows depends on the intensity of the radiation falling on the windows, the transmission and absorption factors for the particular type of glass, and the percentage of the window area that receives direct solar radiation. The transmission and absorption factors depend on the angle at which the radiation strikes the glass surface.

This computer program is written to calculate the solar heat gain of a double-glazed window. It is capable of computing the overall heat transfer coefficient, inward radiation and convection gain, solar heat gain coefficient,

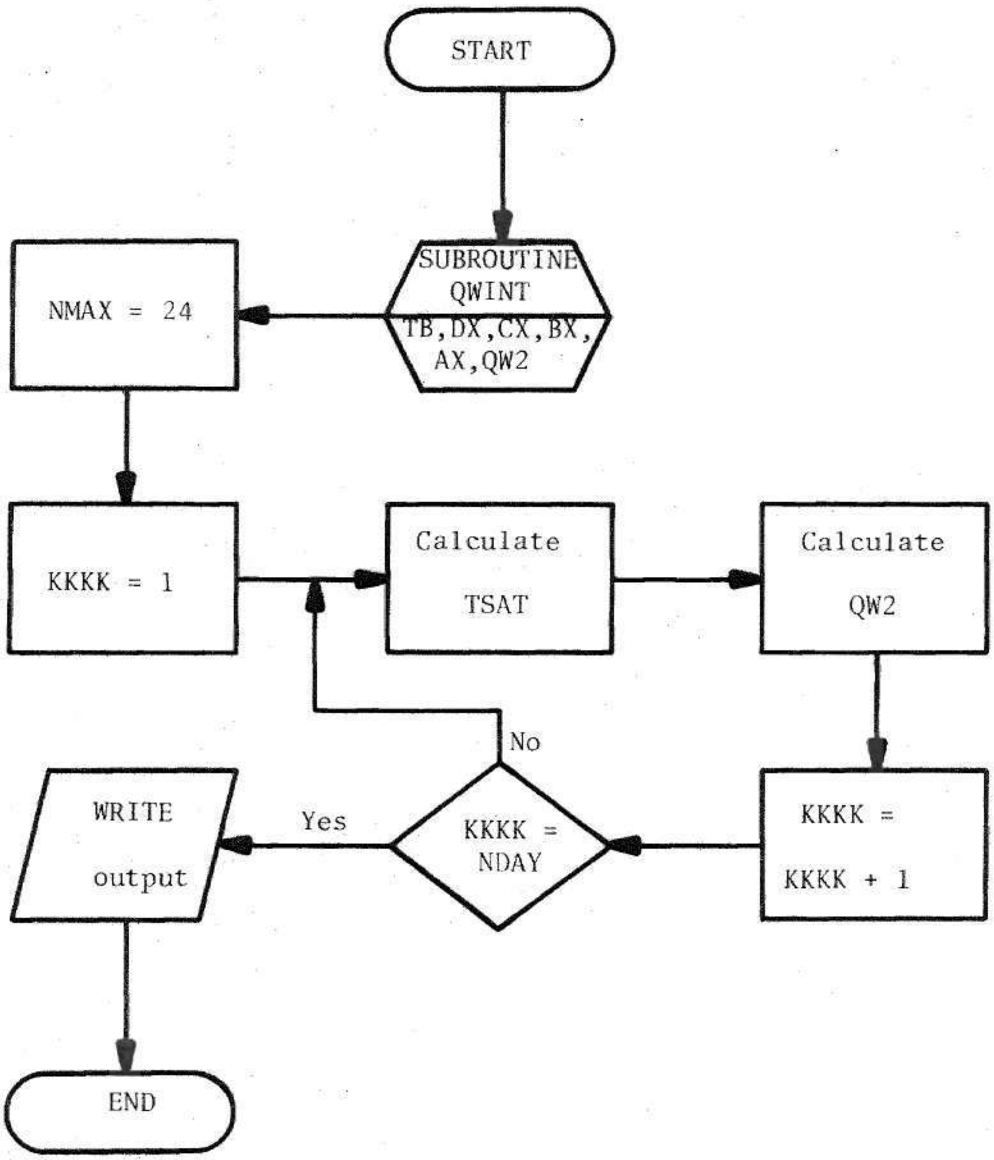


Figure 20. Flow Diagram for Calculation of the Sol-Air Temperatures and the Heat Gain Through the Interior Partitions, Floors and Ceilings as an Independent Program

Table 10. Input and Output of the Computer Program for Calculation of the Solar Heat Gain Through Fenestration

No.	Input	No.	Output
1	RGO	1	U
2	RO2	2	QRCI
3	ALP1	3	F
4	ALP2	4	QA
5	TAU1	5	TO
6	RO3	6	TI
7	ALP3		
8	HO		
9	HI		
10	HS		
11	TAUO		
12	RGI		
13	TO		
14	TI		
15	TSI		
16	SHGF		

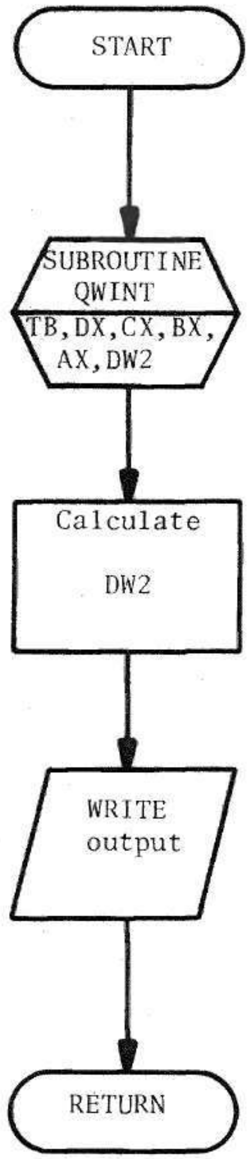


Figure 21. Flow Diagram for Calculation of the Heat Gain Through the Interior Partitions, Floors and Ceilings as a Subroutine

and the solar heat gain through the double-glazed window. For single and multi-layer glass, the computer program should be revised.

6. Cooling Load

The cooling load of a space depends on both the magnitude and the nature of the sensible heat gain (i.e., heat conduction through walls, direct and diffuse solar radiation, electric energy input to light, etc.). It also depends on the location of the space object that absorbs the energy of the heat gain. Each component of the space has some kind of heat gain, and each of them gives rise to a distinct component of cooling load. The latent heat gain component of the cooling load, unlike the other components, may or may not be part of the space load, depending on the type of air-conditioning system (dehumidification of ventilation air may be at a central location rather than in each room [3]). The sum of these various components at any time is the total cooling load at that time.

Similarly to the previous calculations of both heat gains through exterior walls and interior partitions by the transfer function method, the calculation is started by assuming that the previous cooling load is zero. The effect of this assumption on the calculated cooling load values becomes negligible as the calculation is repeated for successive 24-hour cycles. In this computer program, calculations also have been made on nine orientations each

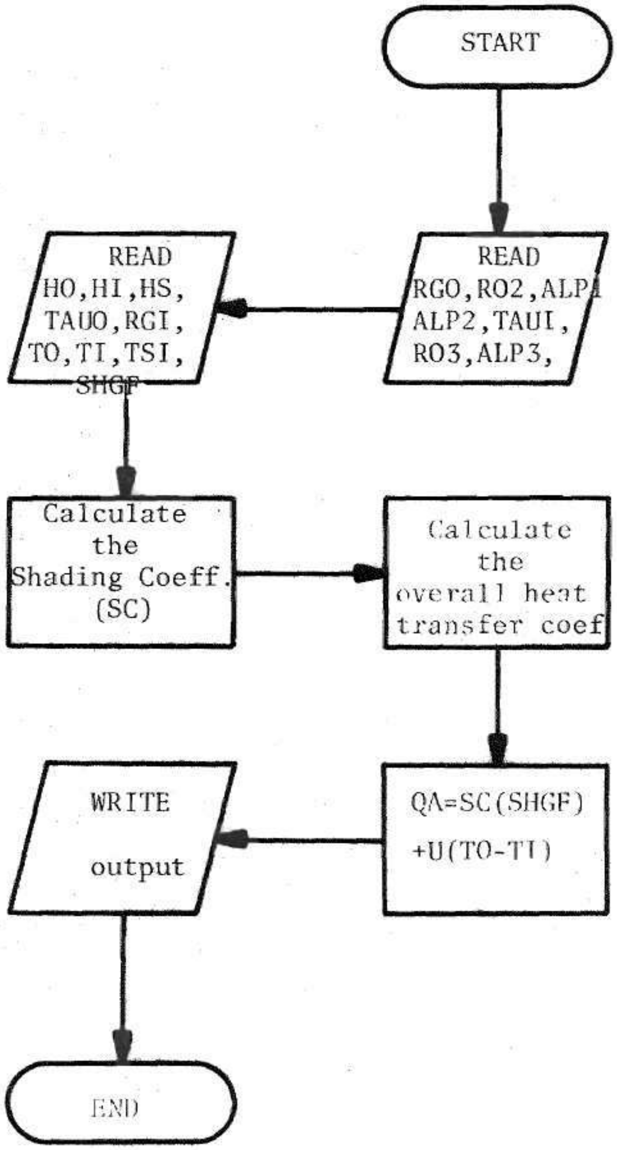


Figure 22. Flow Diagram for Calculation of the Solar Heat Gain Through the Fenestration as an Independent Program

Table 11. Input and Output of the Computer Program for Calculation of the Cooling Load

No.	Input	No.	Output
1	T(I)	1	QR(I,J)
2	AA(I)		
3	GR		
4	A		
5	B		
6	C		
7	DAY		
8	BL(I)		
9	BM(I)		
10	BN(I)		
11	V(I)		
12	W(I)		

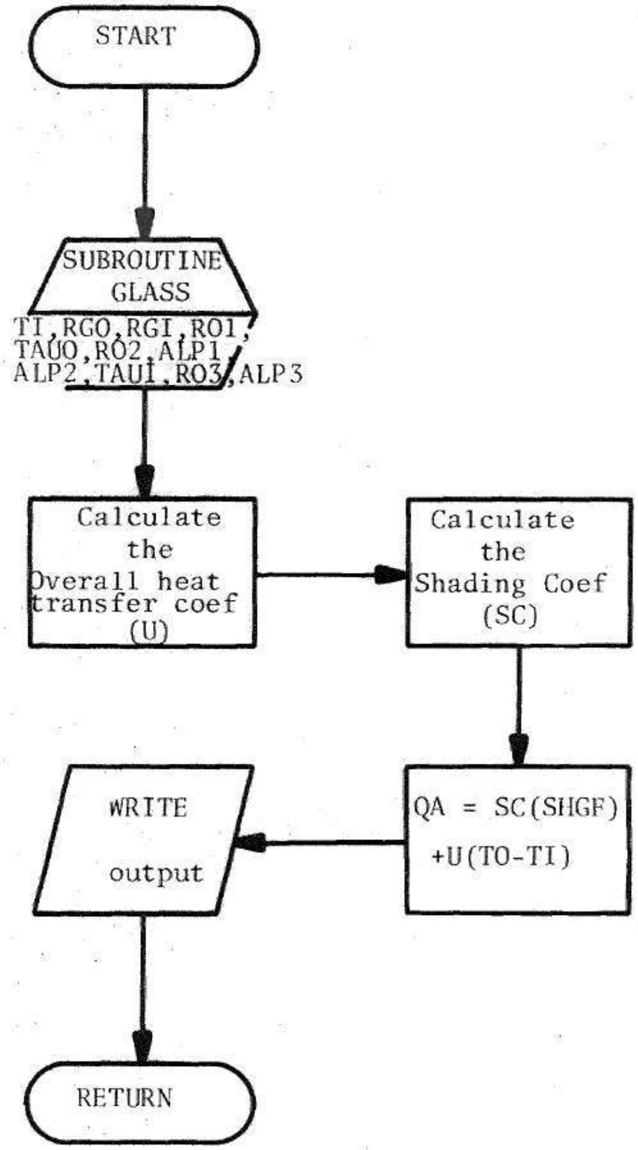


Figure 23. Flow Diagram for Calculation of the Solar Heat Gain Through the Fenestration as a Subroutine

day for 24 hours a day, and selection of desired orientations is made in the same way as in the solar heat gain factor subprograms.

E. General Computer Program for Calculation of the Cooling Load

In this computer program, subroutines are linked together for internal calculation of factors used for calculation of the cooling load of the space to be conditioned. Parameters NMAX and KKKK for choice of number of calculations in a day and number of days in a year should be determined in the main program; when a subroutine is to be executed, the value of these parameters, along with other necessary data for calculation of that particular factor, automatically enters the subroutine. After the execution of the subroutine, all the values that have been used as input and values of the output which have been calculated in that subroutine would shift to the main program for further manipulations in other subroutines. If it is desired that the values of the factors calculated in the different subroutines be printed every time that the value is computed, the "write" statement may be placed within the subroutine itself, and if it is not necessary that the values of these factors be printed, the "write" statement would be ignored. After all the subroutines are executed and all the necessary output is printed, the new values of the parameters are obtained by adding one unit

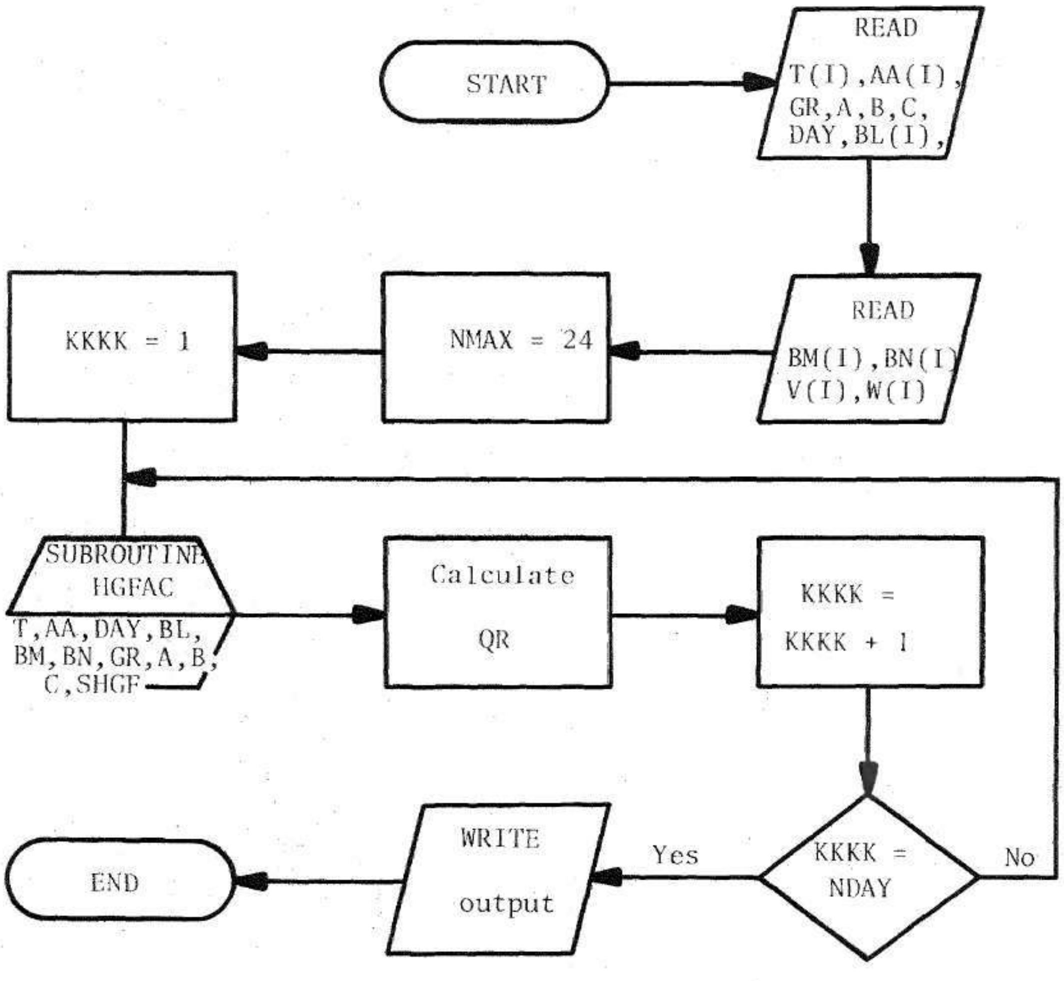


Figure 24. Flow Diagram for Calculation of the Cooling Load as an Independent Program

Table 12. Input and Output of the Computer Program for Cooling Load Estimation

No.	Input	No.	Input	No.	Output
1	NMAX	19	CX(I)	1	TILT
2	V(I)	20	DO(I)	2	D
3	W(I)	21	BO(I)	3	Sunrise
4	T(I)	22	CO(I)	4	Sunset
5	AA(I)	23	RGO	5	Number of possible hours of sunshine
6	DAY	24	RGI		
7	AL	25	TAUO	6	Azimuthal angle for sunrise and sunset
8	GR	26	RO2	7	H(I)
9	A	27	ALP1	8	BITA(I)
10	B	28	ALP2	9	GAMA(I)
11	C	29	TAUI	10	AOIN(I)
12	BL(I)	30	RO3	11	DNI(I)
13	BM(I)	31	ALP3	12	DSI(I)
14	BN(I)	32	HO	13	TI(I)
15	AW(I)	33	HI	14	SHGF(N,I)
16	AX(I)	34	HS	15	TSAI(I,J)
17	DX(I)	35	TO(J)	16	QWI(J,I)
18	BX(I)	36	TB(I)	17	QGLASS
				18	QTOT
				20	QR(I,J)
				21	QW2(J,I)

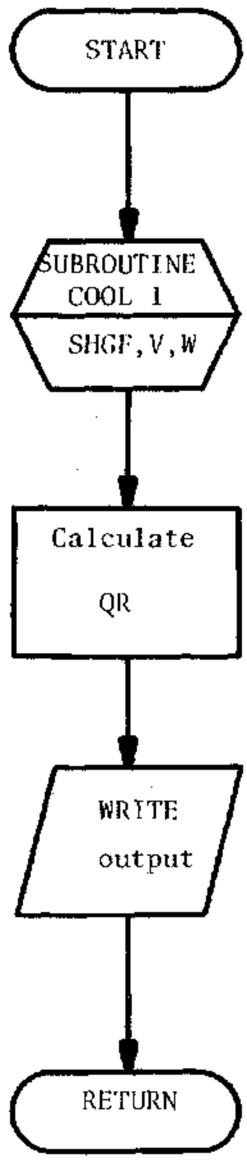


Figure 25. Flow Diagram for Calculation of the Cooling Load as a Subroutine

to the previous values of the parameters, thus indicating execution of the subroutines for one more time in a day or one more day in a year.

This computer program is capable of computing the total heat gain of any of the indicated orientations in three groups: heat gain through the exterior walls, solar heat gain through the glass, and heat gain through the interior walls. The next step would be to calculate a cooling load for the total heat gain at any of the indicated orientations.

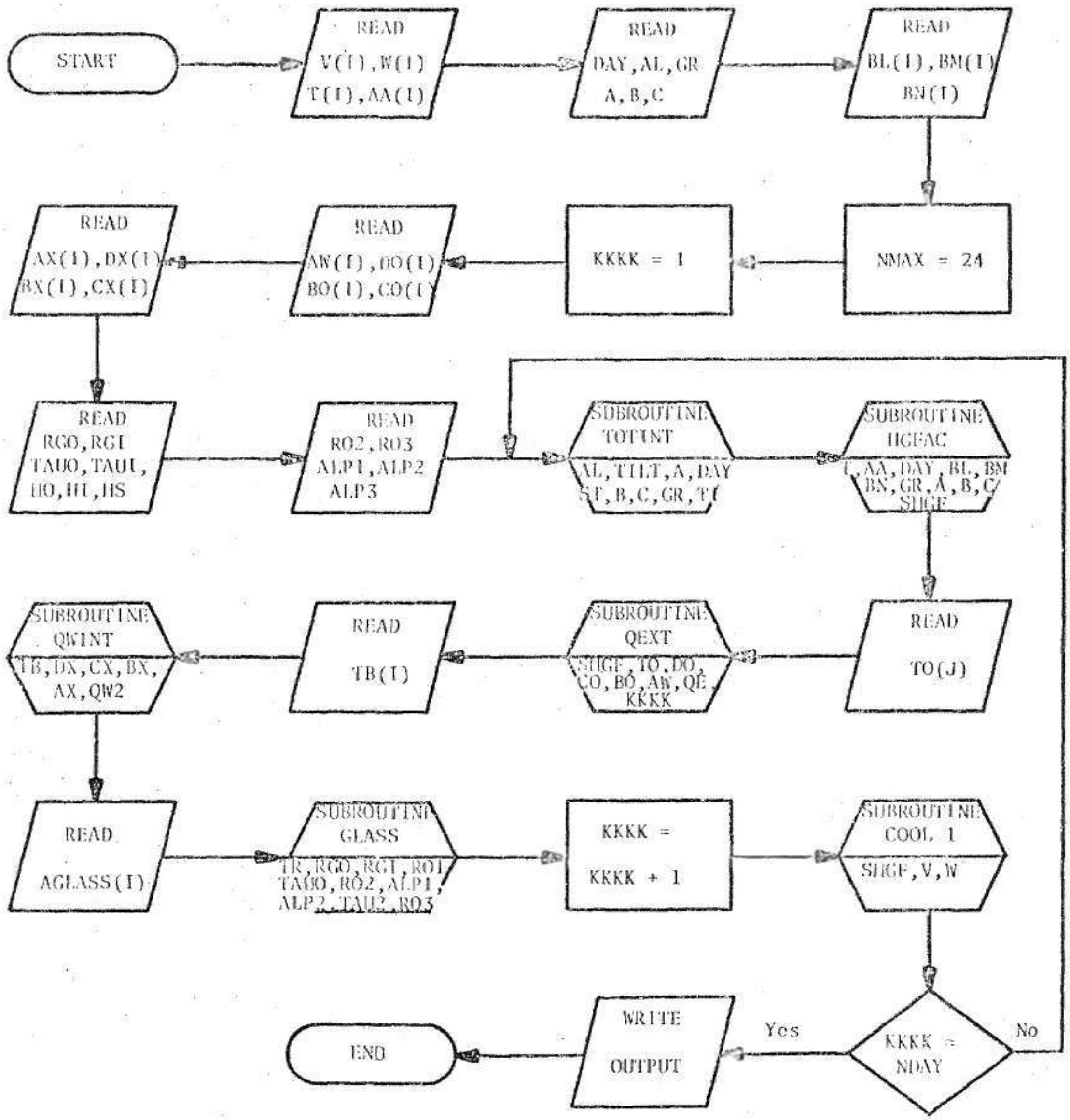


Figure 26. Flow Diagram for the General Program for Calculation of the Cooling Load

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The main feature of this research is the application of transfer function method which has been suggested in ASHRAE Handbook of Fundamentals (1972) [3]. This is particularly well suited for the use of a computer. While such computer programs do exist, the detailed algorithms are not available to everyone. Effort has been made to develop such an algorithm for future research and further improvements. In this algorithm, solar angles and solar radiations as well as the solar heat gain factors and sol-air temperatures have been calculated which are used as data inputs along with the climatic factors for calculation of the heat gain and cooling load (transfer function method) of different zones of the building.

In this method, the evaluation of cooling load is initiated by setting all heat gain values as zero which implies that the thermal storage in exposed wall sections is zero. The minimum days for convergence to offset this assumption will be four consecutive days. The convergence may be checked by computing the average heat gain and cooling load for the fourth day of the period with repeating weather data.

For calculation of inputs into cooling load program, five computer programs have been developed to compute the solar angles and solar radiation, solar heat gain factors, sol-air temperatures and heat gain by conduction through exterior walls and roofs, heat gain by conduction through interior partitions, floors and ceilings, and solar heat gain through fenestrations. These computer programs can also be used as separate programs or as subroutines for calculations of the cooling loads of individual zones and the building as a whole.

Recommendations

Computer programs developed have several limitations that could be removed by modification of the algorithm.

In the calculation of the sol-air temperatures, it has been assumed that for horizontal surfaces the values of the hemispherical emittance of the surface (ε) as unity, coefficient of heat transfer by radiation and convection at the outdoor surface (h_o) is taken as 3.0 Btu/hr-ft^2-°F, the difference between the longwave radiation incident on the surface from the sky and surroundings, and the radiation emitted by a black body at outdoor air temperature (ΔR) equal to about 20 Btu/hr-ft. This value has also been assumed as zero for the vertical surface. For more accurate results, it is possible to choose the real values of these variables as input to the program.

The computer program developed for the calculation of solar heat gain through fenestration has been written for double strength glass with reflective coating on the surface number 3. This program may be used for single light glass by assuming the variables for the second sheet as zones. Other programs may be written for other types of window glasses.

The example problem used to illustrate the computer program does not compute the heat gain for individual rooms, but it considers entire office buildings with no partitions. This deficiency may be removed by applying the algorithm repeatedly for various rooms or zones. In such cases, the cooling load program has to be expanded to compute summation of the building heat gains.

In order to develop a critical load wedge it is necessary to determine the occurrences of maximum sensible, latent and total loads as well as maximum and minimum sensible heat factors. These computations require addition of simple arithmetic statements and comparison of numbers. Computers can do these computations efficeintly using the hourly heat loads generated internally and print the summary of results. These computations need to be done for each zone and for the building as a whole.

The procedure to determine the time of the day and the day of the year for each of these five critical conditions that may occur can best be done by selecting the probable days during which such a situation exists. The summary output of the cooling load program giving these five critical values for each day can be plotted on graph paper. If the curve connecting these points for each of these cases has a positive slope then the program needs to be continued for more numbers of days until the maximum value (zero slope) of this critical value is reached.

On the other hand, if the slope is negative it will be necessary to restart the program for a different period. Here, the user can depend on his judgement to select the period by noting the magnitude of these slopes. If these values are close to zero then the critical loads will occur in the vicinity of initial guesses. If this is not the case it is best to select a different period and restart the program. This may save considerable computer time.

It is hoped that the future researchers will catalog these experiences with location, type of structures, orientation and climatic conditions as parameters. An air conditioning consultant can draw these experiences and develop a balance design of environmental systems having superior performance factors.

APPENDICES

APPENDIX A

COMPUTER PROGRAMS

Input data for calculation of the solar angles and radiations:

```
AL    = 40.0
TILT  = 30.0
A     = 344.0
DAY   = 202
SI    = 45.0
BB    = .2070
C     = .1360
GR    = .2000
ST(I) = 1 through 24
```

```
      PARAMETER NMAX=24
       DIMENSION H1(NMAX),H2(NMAX),ST(NMAX),
     -BITA1(NMAX),BITA2(NMAX),AZ1(NMAX),AZ2(NMAX),DNI (NMAX),
     -WSAZ1(NMAX),WSAZ2(NMAX),AOIN1(NMAX),AOIN2(NMAX),
     1DSI(NMAX),THI(NMAX),
     -DGI(NMAX),TI(NMAX)
      READ(5,1)AL,TILT,A,DAY,SI
    1 FORMAT(F5.1)
      READ(5,50)BB,C,GR
   50 FORMAT(F5.4)
      READ(5,3) (ST(I), I=1,NMAX)
      KKKK=1.
      AL=AL/57.3
      TILT1=TILT
 1000 CONTINUE
    3 FORMAT(F5.0)
      NWALL=4
      WRITE(6,4)TILT1
    4 FORMAT(1H1,2X,'THE SOLAR RADIATION DATA FOR 40 DEGREES N LATITUDE
     -ON THE ROOF WITH',F4.0,'SLOPE FACING SE ARE PRINTED BELOW'/)
      IF(KKKK.EQ.1) WRITE(6,1001)
      IF(KKKK.EQ.2) WRITE(6,1002)
      IF(KKKK.EQ.3) WRITE(6,1003)
      IF(KKKK.EQ.4) WRITE(6,1004)
 1001 FORMAT(15X,'DATE: JULY 21'/)
 1002 FORMAT(15X,'DATE: JULY 22'/)
 1003 FORMAT(15X,'DATE: JULY 23'/)
 1004 FORMAT(15X,'DATE: JULY 24'/)
      TILT=TILT/57.3
      DDDD=KKKK-1
      DAY=202.+DDDD
      D=23.5*SIN((DAY-80.)*360./(365.*57.3))
      ID=D
      AI=ID
      SEC=(D-AI)*60.
      SEC=ABS(SEC)
```

```
      WRITE(6,5) ID,SEC
    5 FORMAT(5X,'DECLINATION ANGLE=',I4,'DEGREES',F4.0,'MINUTES')
      D=D/57.3
      AD=D
      AI=SIN(AL)*SIN(D)/(COS(AL)*COS(D))
      AI=ATAN(SQRT(1.-AI*AI)/AI)
      IF (AI.LT.0.) AI=AI+4.*ATAN(1.)
      HSS=AI
      TMI=4.*AI/60.*57.3
      IH=TMI
      AI=IH
      AI=(TMI-AI)*60.
      AI=ABS(AI)
      WRITE(6,6)IH,AI
    6 FORMAT(5X,'SUN RISE IS AT',I4,':',F4.0,'AM.')
      HRS=12.-TMI
      IH=HRS
      AI=IH
      AI=(HRS-AI)*60.
      AI=ABS(AI)
      WRITE(6,7)IH,AI
    7 FORMAT(5X,'SUN  SET IS AT',I4,':',F4.0,'PM.')
      HPSS=2.*HSS/15.*57.3
      HPSS=24.-HPSS
      IH=HPSS
      AI=IH
      AI=(HPSS-AI)*60.
      AI=ABS(AI)
      WRITE(6,8)IH,AI
    8 FORMAT(5X,'NO. OF POSSIBLE HOURS OF SUNSHINE',I4,':',F4.0)
      G=COS(AL)*SIN(AD)-COS(AD)*SIN(AL)*SIN(HSS)
      G= ATAN(SQRT(1.-G*G)/G)
      IF(G.LT.0.) G=G+4.*ATAN(1.)
      GG=G*57.3
      IH=GG
      AI=IH
```

```
      G=G*57.3
      IH=G
      AI=IH
      AI=(G-AI)*60.
      AI=ABS(AI)
      AZ1(I)=G
      AZ2(I)=AI
      SI=+(FLOAT(NWALL)-5.)*45.
      IF(ST(I).GT.12.) SI=-(FLOAT(NWALL)-5.)*45.
      ALPHA=G-SI
      IH=ALPHA
      AI=IH
      WSAZ1(I)=IH
      WSAZ2(I)=(ALPHA-AI)*60.
      WSAZ2(I)=ABS(WSAZ2(I))
      ALP=ABS(5.-AWALL)*45./57.3
      TT=COS(B/57.3)*COS(ALP)*COS(TILT)+SIN(B/57.3)*SIN(TILT)
      TT=ATAN(SQRT(1.-TT*TT)/TT)
      IF(TT.LT.0.) TT=TT+4.*ATAN(1.)
      AWALL=NWALL
      TT=TT*57.3
      IH=TT
      AI=IH
      AI=(TT-AI)*60.
      AI=ABS(AI)
      AOIN1(I)=IH
      AOIN2(I)=AI
      DNI(I)=A/EXP(BB/SIN(B/57.3))
      IF(B.LT.0)DNI(I)=0.
      FSQ=0.5*(1.-COS(TILT))
      FSS=1.-FSQ
      DSI(I)=C*DNI(I)*FSS
      THI(I)=DNI(I)*(C+SIN(B/57.3))
      DGI(I)=THI(I)*GR*FSQ
      TI(I)=DNI(I)+DSI(I)+DGI(I)
      I1=H1(I)
```

```
      I2=H2(I)
      I3=BITA1(I)
      I4=BITA2(I)
      I6=AZ2(I)
      I5=AZ1(I)
      I7=AOIN1(I)
      I8=AOIN2(I)
      WRITE (6,11) I,I1,I2,I3,I4,I5,I6,I7,I8,DNI(I),DSI(I),TI(I)
   11 FORMAT(5X,'HOUR=',I2,1X,'H=',I3  ,':',I1  ,1X,'BITA=',I3  ,
     -':',I2  ,1X,'GAMA=',I3  ,':',I2  ,1X,'AOIN=',I3       ,
     -':',I2  ,1X,'DNI=',F6.2,1X,'DSI=',F5.2,1X,'TI=',F6.2)
   10 CONTINUE
      KKKK=KKKK+1
      IF(KKKK.EQ.5)STOP
      GO TO 1000
      END
```

DATE: JULY 21

DECLINATION ANGLE= 20DEGREES 17.MINUTES
SUN RISE IS AT 4: 48.AM.
SUN SET IS AT 7: 12.PM.
NO. OF POSSIBLE HOURS OF SUNSHINE 14: 24.
AZIMUTHAL ANGLE FOR SUNRISE IS 107DEGREES 55.MINUTES.

TIME	HOUR ANGLE	ALTITUTE	ANGLE OF AZIMUTH	ANGLE OF INCIDENT	DIRECT NORMAL INTENSITY	DEFFUSE SOLAR INTENSITY	TOTAL INTENSITY
HOUR= 1	H=165:0	BITA=-28: 6	GAMA= 15:59	AOIN=140:53	DNI= .00	DSI= .00	TI= .00
HOUR= 2	H=150:0	BITA=-23:32	GAMA= 30:46	AOIN= 68:47	DNI= .00	DSI= .00	TI= .00
HOUR= 3	H=135:0	BITA=-16:34	GAMA= 43:48	AOIN= 63:37	DNI= .00	DSI= .00	TI= .00
HOUR= 4	H=120:0	BITA= -7:50	GAMA= 55: 5	AOIN= 57:25	DNI= .00	DSI= .00	TI= .00
HOUR= 5	H=105:0	BITA= 2: 7	GAMA= 65: 3	AOIN= 50:55	DNI= 1.27	DSI= .16	TI= 1.43
HOUR= 6	H= 90:0	BITA= 12:52	GAMA= 74:12	AOIN= 44:53	DNI=135.91	DSI=17.25	TI=153.81
HOUR= 7	H= 75:0	BITA= 24: 8	GAMA= 83: 6	AOIN= 40:14	DNI=207.34	DSI=26.31	TI=235.17
HOUR= 8	H= 60:0	BITA= 35:36	GAMA= 92:32	AOIN= 37:54	DNI=241.07	DSI=30.59	TI=273.97
HOUR= 9	H= 45:0	BITA= 46:58	GAMA=103:37	AOIN= 38:25	DNI=259.16	DSI=32.89	TI=295.06
HOUR=10	H= 30:0	BITA= 57:41	GAMA=118:41	AOIN= 41:25	DNI=269.27	DSI=34.17	TI=306.98
HOUR=11	H= 15:0	BITA= 66:29	GAMA=142:32	AOIN= 45:20	DNI=274.48	DSI=34.83	TI=313.18
HOUR=12	H= 0:0	BITA= 70:17	GAMA=179:58	AOIN= 47:22	DNI=276.10	DSI=35.03	TI=315.12
HOUR=13	H= 15:0	BITA= 66:29	GAMA=142:32	AOIN= 45:20	DNI=274.48	DSI=34.83	TI=313.18
HOUR=14	H= 30:0	BITA= 57:41	GAMA=118:41	AOIN= 41:25	DNI=269.27	DSI=34.17	TI=306.98
HOUR=15	H= 45:0	BITA= 46:58	GAMA=103:37	AOIN= 38:25	DNI=259.16	DSI=32.89	TI=295.06
HOUR=16	H= 60:0	BITA= 35:36	GAMA= 92:32	AOIN= 37:54	DNI=241.07	DSI=30.59	TI=273.97
HOUR=17	H= 75:0	BITA= 24: 8	GAMA= 83: 6	AOIN= 40:14	DNI=207.34	DSI=26.31	TI=235.17
HOUR=18	H= 90:0	BITA= 12:52	GAMA= 74:12	AOIN= 44:53	DNI=135.91	DSI=17.25	TI=153.81
HOUR=19	H=105:0	BITA= 2: 7	GAMA= 65: 3	AOIN= 50:55	DNI= 1.27	DSI= .16	TI= 1.43
HOUR=20	H=120:0	BITA= -7:50	GAMA= 55: 5	AOIN= 57:25	DNI= .00	DSI= .00	TI= .00
HOUR=21	H=135:0	BITA=-16:34	GAMA= 43:48	AOIN= 63:37	DNI= .00	DSI= .00	TI= .00
HOUR=22	H=150:0	BITA=-23:32	GAMA= 30:46	AOIN= 68:47	DNI= .00	DSI= .00	TI= .00
HOUR=23	H=165:0	BITA=-28: 6	GAMA= 15:59	AOIN= 72:16	DNI= .00	DSI= .00	TI= .00
HOUR=24	H=180:0	BITA=-29:43	GAMA= 0: 1	AOIN= 73:30	DNI= .00	DSI= .00	TI= .00

DATE: JULY 22

DECLINATION ANGLE= 20DEGREES 5.MINUTES
SUN RISE IS AT 4: 49.AM.
SUN SET IS AT 7: 11.PM.
NO. OF POSSIBLE HOURS OF SUNSHINE 14: 23.
AZIMUTHAL ANGLE FOR SUNRISE IS 108DEGREES 10.MINUTES.

TIME	HOUR ANGLE	ALTITUTE	ANGLE OF AZIMUTH	ANGLE OF INCIDENT	DIRECT NORMAL INTENSITY	DEFFUSE SOLAR INTENSITY	TOTAL INTENSITY
HOUR= 1	H=165:0	BITA=-28:19	GAMA= 16: 2	AOIN= 51:49	DNI= .00	DSI= .00	TI= .00
HOUR= 2	H=150:0	BITA=-23:43	GAMA= 30:52	AOIN= 49:56	DNI= .00	DSI= .00	TI= .00
HOUR= 3	H=135:0	BITA=-16:44	GAMA= 43:55	AOIN= 47:35	DNI= .00	DSI= .00	TI= .00
HOUR= 4	H=120:0	BITA= -7:59	GAMA= 55:14	AOIN= 45:39	DNI= .00	DSI= .00	TI= .00
HOUR= 5	H=105:0	BITA= 1:58	GAMA= 65:12	AOIN= 45: 0	DNI= .85	DSI= .12	TI= .97
HOUR= 6	H= 90:0	BITA= 12:45	GAMA= 74:22	AOIN= 46:14	DNI=134.67	DSI=18.31	TI=152.99
HOUR= 7	H= 75:0	BITA= 24: 0	GAMA= 83:17	AOIN= 49:29	DNI=206.84	DSI=28.13	TI=234.97
HOUR= 8	H= 60:0	BITA= 35:29	GAMA= 92:44	AOIN= 54:28	DNI=240.81	DSI=32.75	TI=273.56
HOUR= 9	H= 45:0	BITA= 46:50	GAMA=103:52	AOIN= 60:38	DNI=259.01	DSI=35.22	TI=294.24
HOUR=10	H= 30:0	BITA= 57:32	GAMA=118:57	AOIN= 67:13	DNI=269.16	DSI=36.61	TI=305.77
HOUR=11	H= 15:0	BITA= 66:18	GAMA=142:48	AOIN= 72:59	DNI=274.40	DSI=37.32	TI=311.71
HOUR=12	H= 0:0	BITA= 70: 5	GAMA=179:59	AOIN= 75:33	DNI=276.02	DSI=37.54	TI=313.56
HOUR=13	H= 15:0	BITA= 66:18	GAMA=142:48	AOIN= 72:59	DNI=274.40	DSI=37.32	TI=311.71
HOUR=14	H= 30:0	BITA= 57:32	GAMA=118:57	AOIN= 67:13	DNI=269.16	DSI=36.61	TI=305.77
HOUR=15	H= 45:0	BITA= 46:50	GAMA=103:52	AOIN= 60:38	DNI=259.01	DSI=35.22	TI=294.24
HOUR=16	H= 60:0	BITA= 35:29	GAMA= 92:44	AOIN= 54:28	DNI=240.81	DSI=32.75	TI=273.56
HOUR=17	H= 75:0	BITA= 24: 0	GAMA= 83:17	AOIN= 49:29	DNI=206.84	DSI=28.13	TI=234.97
HOUR=18	H= 90:0	BITA= 12:45	GAMA= 74:22	AOIN= 46:14	DNI=134.67	DSI=18.31	TI=152.99
HOUR=19	H=105:0	BITA= 1:58	GAMA= 65:12	AOIN= 45: 0	DNI= .85	DSI= .12	TI= .97
HOUR=20	H=120:0	BITA= -7:59	GAMA= 55:14	AOIN= 45:39	DNI= .00	DSI= .00	TI= .00
HOUR=21	H=135:0	BITA=-16:44	GAMA= 43:55	AOIN= 47:35	DNI= .00	DSI= .00	TI= .00
HOUR=22	H=150:0	BITA=-23:43	GAMA= 30:52	AOIN= 49:56	DNI= .00	DSI= .00	TI= .00
HOUR=23	H=165:0	BITA=-28:19	GAMA= 16: 2	AOIN= 51:49	DNI= .00	DSI= .00	TI= .00
HOUR=24	H=180:0	BITA=-29:55	GAMA= 0: 1	AOIN= 52:32	DNI= .00	DSI= .00	TI= .00

DATE: JULY 23

DECLINATION ANGLE= 19DEGREES 52.MINUTES
SUN RISE IS AT 4: 49.AM.
SUN SET IS AT 7: 11.PM.
NO. OF POSSIBLE HOURS OF SUNSHINE 14: 21.
AZIMUTHAL ANGLE FOR SUNRISE IS 108DEGREES 25.MINUTES.

TIME	HOUR ANGLE	ALTITUTE	ANGLE OF AZIMUTH	ANGLE OF INCIDENT	DIRECT NORMAL INTENSITY	DEFFUSE SOLAR INTENSITY	TOTAL INTENSITY
HOUR= 1	H=165:0	BITA=-28:31	GAMA= 16: 5	AOIN= 51:35	DNI= .00	DSI= .00	TI= .00
HOUR= 2	H=150:0	BITA=-23:55	GAMA= 30:58	AOIN= 49:44	DNI= .00	DSI= .00	TI= .00
HOUR= 3	H=135:0	BITA=-16:55	GAMA= 44: 2	AOIN= 47:25	DNI= .00	DSI= .00	TI= .00
HOUR= 4	H=120:0	BITA= -8: 9	GAMA= 55:22	AOIN= 45:34	DNI= .00	DSI= .00	TI= .00
HOUR= 5	H=105:0	BITA= 1:50	GAMA= 65:21	AOIN= 45: 1	DNI= .53	DSI= .07	TI= .61
HOUR= 6	H= 90:0	BITA= 12:37	GAMA= 74:32	AOIN= 46:21	DNI=133.38	DSI=18.14	TI=151.52
HOUR= 7	H= 75:0	BITA= 23:53	GAMA= 83:29	AOIN= 49:42	DNI=206.33	DSI=28.06	TI=234.39
HOUR= 8	H= 60:0	BITA= 35:21	GAMA= 92:57	AOIN= 54:46	DNI=240.55	DSI=32.72	TI=273.27
HOUR= 9	H= 45:0	BITA= 46:42	GAMA=104: 7	AOIN= 60:59	DNI=258.85	DSI=35.20	TI=294.06
HOUR=10	H= 30:0	BITA= 57:23	GAMA=119:14	AOIN= 67:35	DNI=269.05	DSI=36.59	TI=305.64
HOUR=11	H= 15:0	BITA= 66: 7	GAMA=143: 3	AOIN= 73:21	DNI=274.31	DSI=37.31	TI=311.61
HOUR=12	H= 0:0	BITA= 69:52	GAMA=179:59	AOIN= 75:54	DNI=275.94	DSI=37.53	TI=313.46
HOUR=13	H= 15:0	BITA= 66: 7	GAMA=143: 3	AOIN= 73:21	DNI=274.31	DSI=37.31	TI=311.61
HOUR=14	H= 30:0	BITA= 57:23	GAMA=119:14	AOIN= 67:35	DNI=269.05	DSI=36.59	TI=305.64
HOUR=15	H= 45:0	BITA= 46:42	GAMA=104: 7	AOIN= 60:59	DNI=258.85	DSI=35.20	TI=294.06
HOUR=16	H= 60:0	BITA= 35:21	GAMA= 92:57	AOIN= 54:46	DNI=240.55	DSI=32.72	TI=273.27
HOUR=17	H= 75:0	BITA= 23:53	GAMA= 83:29	AOIN= 49:42	DNI=206.33	DSI=28.06	TI=234.39
HOUR=18	H= 90:0	BITA= 12:37	GAMA= 74:32	AOIN= 46:21	DNI=133.38	DSI=18.14	TI=151.52
HOUR=19	H=105:0	BITA= 1:50	GAMA= 65:21	AOIN= 45: 1	DNI= .53	DSI= .07	TI= .61
HOUR=20	H=120:0	BITA= -8: 9	GAMA= 55:22	AOIN= 45:34	DNI= .00	DSI= .00	TI= .00
HOUR=21	H=135:0	BITA=-16:55	GAMA= 44: 2	AOIN= 47:25	DNI= .00	DSI= .00	TI= .00
HOUR=22	H=150:0	BITA=-23:55	GAMA= 30:58	AOIN= 49:44	DNI= .00	DSI= .00	TI= .00
HOUR=23	H=165:0	BITA=-28:31	GAMA= 16: 5	AOIN= 51:35	DNI= .00	DSI= .00	TI= .00
HOUR=24	H=180:0	BITA=-30: 8	GAMA= 0: 1	AOIN= 52:18	DNI= .00	DSI= .00	TI= .00

DATE: JULY 24

DECLINATION ANGLE= 19DEGREES 39.MINUTES
SUN RISE IS AT 4: 50.AM.
SUN SET IS AT 7: 10.PM.
NO. OF POSSIBLE HOURS OF SUNSHINE 14: 19.
AZIMUTHAL ANGLE FOR SUNRISE IS 108DEGREES 40.MINUTES.

TIME	HOUR ANGLE	ALTITUTE	ANGLE OF AZIMUTH	ANGLE OF INCIDENT	DIRECT NORMAL INTENSITY	DEFFUSE SOLAR INTENSITY	TOTAL INTENSITY
HOUR= 1	H=165:0	BITA=-28:44	GAMA= 16: 9	AOIN= 51:41	DNI= .00	DSI= .00	TI= .00
HOUR= 2	H=150:0	BITA=-24: 7	GAMA= 31: 4	AOIN= 49:48	DNI= .00	DSI= .00	TI= .00
HOUR= 3	H=135:0	BITA=-17: 5	GAMA= 44:10	AOIN= 47:28	DNI= .00	DSI= .00	TI= .00
HOUR= 4	H=120:0	BITA= -8:18	GAMA= 55:31	AOIN= 45:35	DNI= .00	DSI= .00	TI= .00
HOUR= 5	H=105:0	BITA= 1:41	GAMA= 65:31	AOIN= 45: 1	DNI= .30	DSI= .04	TI= .35
HOUR= 6	H= 90:0	BITA= 12:29	GAMA= 74:42	AOIN= 46:20	DNI=132.03	DSI=17.96	TI=149.99
HOUR= 7	H= 75:0	BITA= 23:45	GAMA= 83:40	AOIN= 49:40	DNI=205.79	DSI=27.99	TI=233.78
HOUR= 8	H= 60:0	BITA= 35:14	GAMA= 93:10	AOIN= 54:43	DNI=240.28	DSI=32.68	TI=272.96
HOUR= 9	H= 45:0	BITA= 46:34	GAMA=104:22	AOIN= 60:55	DNI=258.69	DSI=35.18	TI=293.87
HOUR=10	H= 30:0	BITA= 57:14	GAMA=119:32	AOIN= 67:30	DNI=268.94	DSI=36.58	TI=305.51
HOUR=11	H= 15:0	BITA= 65:55	GAMA=143:19	AOIN= 73:14	DNI=274.22	DSI=37.29	TI=311.51
HOUR=12	H= 0:0	BITA= 69:39	GAMA=179:58	AOIN= 75:46	DNI=275.85	DSI=37.52	TI=313.37
HOUR=13	H= 15:0	BITA= 65:55	GAMA=143:19	AOIN= 73:14	DNI=274.22	DSI=37.29	TI=311.51
HOUR=14	H= 30:0	BITA= 57:14	GAMA=119:32	AOIN= 67:30	DNI=268.94	DSI=36.58	TI=305.51
HOUR=15	H= 45:0	BITA= 46:34	GAMA=104:22	AOIN= 60:55	DNI=258.69	DSI=35.18	TI=293.87
HOUR=16	H= 60:0	BITA= 35:14	GAMA= 93:10	AOIN= 54:43	DNI=240.28	DSI=32.68	TI=272.96
HOUR=17	H= 75:0	BITA= 23:45	GAMA= 83:40	AOIN= 49:40	DNI=205.79	DSI=27.99	TI=233.78
HOUR=18	H= 90:0	BITA= 12:29	GAMA= 74:42	AOIN= 46:20	DNI=132.03	DSI=17.96	TI=149.99
HOUR=19	H=105:0	BITA= 1:41	GAMA= 65:31	AOIN= 45: 1	DNI= .30	DSI= .04	TI= .35
HOUR=20	H=120:0	BITA= -8:18	GAMA= 55:31	AOIN= 45:35	DNI= .00	DSI= .00	TI= .00
HOUR=21	H=135:0	BITA=-17: 5	GAMA= 44:10	AOIN= 47:28	DNI= .00	DSI= .00	TI= .00
HOUR=22	H=150:0	BITA=-24: 7	GAMA= 31: 4	AOIN= 49:48	DNI= .00	DSI= .00	TI= .00
HOUR=23	H=165:0	BITA=-28:44	GAMA= 16: 9	AOIN= 51:41	DNI= .00	DSI= .00	TI= .00
HOUR=24	H=180:0	BITA=-30:21	GAMA= 0: 1	AOIN= 52:24	DNI= .00	DSI= .00	TI= .00

<u>Input data for calculation of the solar heat gain factors</u>:

T(1)	= -0.00885	AA(1)	= 0.01154				
T(2)	= 2.71235	AA(2)	= 0.77674				
T(3)	= -0.62062	AA(3)	= -3.94657				
T(4)	= -7.07329	AA(4)	= 8.57881				
T(5)	= 9.75995	AA(5)	= -8.38135				
T(6)	= -3.89922	AA(6)	= 3.01188				
DAY	= 202						
AL	= 40.						
GR	= .2						
A	= 344.						
B	= .207						
C	= .136						
BL(1)	= 0.	BM(1)	= 0.	BN(1)	= -1.		
BL(2)	= 0.	BM(2)	= .707	BN(2)	= -.707		
BL(3)	= 0.	BM(3)	= 1.	BN(3)	= 0.		
BL(4)	= 0.	BM(4)	= .707	BN(4)	= .707		
BL(5)	= 0.	BM(5)	= 0.	BN(5)	= 1.		
BL(6)	= 0.	BM(6)	= -.707	BN(6)	= .707		
BL(7)	= 0.	BM(7)	= -1.	BN(7)	= 0.		
BL(8)	= 0.	BM(8)	= -.707	BN(8)	= -.707		
BL(9)	= 1.	BM(9)	= 0.	BN(9)	= 0.		

```
      DIMENSION T(6),AA(6),SHGF(9,24),AZ1(24),AZ2(24),
     -BITA1(24),BITA2(24),DNI(24),BL(9),BM(9),BN(9)
      READ(5,16) (T(I),AA(I),I=1,6)
      READ (5,111) DAY,AL,GR,A,B,C
   16 FORMAT(2F10.5)
  111 FORMAT(F10.5)
      KKKK=1
      READ(5,17) (BL(I),BM(I),BN(I),I=1,9)
      AL=AL/57.3
 2000 CONTINUE
      WRITE(6,2005)
      WRITE (6,1000)   AL
 2005 FORMAT(1H1)
 1000 FORMAT('THE SOLAR RADIATION DATA FOR ',F3.0,'AREPRINTED BELOW.')
      IF(KKKK.EQ.1) WRITE(6,2001)
      IF(KKKK.EQ.2) WRITE(6,2002)
      IF(KKKK.EQ.3) WRITE(6,2003)
      IF(KKKK.EQ.4) WRITE(6,2004)
 2001 FORMAT(15X,'DATE:JULY 21')
 2002 FORMAT(15X,'DATE:JULY 22')
 2003 FORMAT(15X,'DATE:JULY 23')
 2004 FORMAT(15X,'DATE:JULY 24')
      NMAX=24
      DDDD=KKKK-1
      DAY=202.+DDDD
      D=23.5*SIN((DAY-80.)*360./(365.*57.3))
      ID=D
      AI=ID
      SEC=(D-AI)*60.
      SEC=ABS(SEC)
      WRITE(6,5) ID,SEC
    5 FORMAT(5X,'DECLINATION ANGLE=',I4,'DEGREES',F4.0,'MINUTES'/)
      D=D/57.3
      DO 12 NWALL=1,9
      WL=BL(NWALL)
      WM=BM(NWALL)
```

```
      WN=BN(NWALL)
   17 FORMAT (3F10.3)
      NBY2=NMAX/2
      DO 12 I=1,NBY2
      AI=I
      MAN=AI*60.
      MAN=ABS(MAN-720.)
      H=MAN/4.
      AI=ABS(I-12)
      FF=COS(AI*15./57.3)
      AAA=SIN(AL)*SIN(D)+COS(D)*COS(AL)*COS(AI*15./57.3)
      BB=COS(D)*SIN(AI*15./57.3)
      CC=SQRT(1.-AAA*AAA-BB*BB)
      XXX=ATAN(AAA/SQRT(1.-AAA*AAA))*57.3
      IH=XXX
      AI=IH
      BITA1(I)=IH
      BITA2(I)=ABS((XXX-AI)*60.)
      G=(COS(AL)*SIN(D)-COS(D)*SIN(AL)*COS(H/57.3))/COS(XXX/57.3)
      IF(ABS(G).GE.1.) GO TO 253
      G=ATAN(SQRT(1.-G*G)/G)
      IF(G.LT.0.) G=G+4.*ATAN(1.)
  253 IF(ABS(G).GE.1.) G=0.
      G=G*57.3
      IH=G
      AI=IH
      AI=(G-AI)*60.
      AZ1(I)=G
      AZ2(I)=ABS(AI)
      IF(AAA.LE.0.) GO TO 123
      DNI(I)=A/EXP(B/AAA)
  123 CONTINUE
      GG=SIN(D)*COS(AL)/(COS(D)*SIN(AL))
      IF(FF.LT.GG)    CC=-CC
      THA=WL*AAA+WM*BB+WN*CC
      SUM1=0.
```

```
      SUM2=0.
      SUM3=0.
      SUM4=0.
      IF(ABS(THA).LE..0001) GO TO 124
      ZZZZ=1./THA
  124 IF(ABS(THA).LE..0001) ZZZZ=0.
      DO 13 J=1,6
      AJ=J-1
      ZZZZ=ZZZZ*THA
      SUM1=SUM1+T(J)*ZZZZ
      SUM2=SUM2+AA(J)*ZZZZ
      SUM3=SUM3+T(J)/(AJ+2.)
      SUM4=SUM4+AA(J)/(AJ+2.)
   13 CONTINUE
      DI=0.
      IF(THA.GT.0.) DI=DNI(I)*THA
      F=THA
      IF(F.GT.-.2)Y=.55+.437*F+.313*F*F
      IF(F.LE.-.2)Y=0.45
      DHI=C*DNI(I)
      DVI=DHI
      IF(NWALL.LT.9)  DVI=DNI(I)*(C*Y+.5*GR*(C+AAA))
      SHGT=DI*SUM1+2.*DVI*SUM3
      SHGA=DI*SUM2+2.*DVI*SUM4
      SHGF(NWALL,I)=SHGT+.267*SHGA
      BITA1(24-I)=BITA1(I)
      BITA2(24-I)=BITA2(I)
      DNI(24-I)=DNI(I)
      SHGF(NWALL,24-I)=SHGF(NWALL,I)
   12 CONTINUE
      DO 14 NWALL=2,8
      DO 14 I=1,12
   14 SHGF(10-NWALL,24-I)=SHGF(NWALL,I)
      WRITE (6,18)
   18 FORMAT(2X,'HOUR',3X,'DNI',4X,'ALT',16X,'SOLAR HEAT GAIN FACTORS')
      WRITE (6,19)
```

```
      19 FORMAT(24X,'N',5X,'NE',6X,'E',5X,'SE',6X,'S',5X,'SW',6X,'W',5X,
        1'NW',2X,'HORIZONTAL')
         DO 20 I=1,NMAX
         IF(DNI(I).LE.000001) GO TO 20
         I1=BITA1(I)
         I2=BITA2(I)
         WRITE (6,21) I,DNI(I),I1,I2,(SHGF(N,I),N=1,9)
      21 FORMAT(3X,I2,2X,F6.2,1X,I3,':',I2,1X,F6.2,1X,F6.2,1X,
        1F6.2,1X,F6.2,1X,F6.2,1X,F6.2,1X,F6.2,1X,F6.2 ,1X,F6.2)
      20 CONTINUE
         KKKK=KKKK+1
         IF(KKKK.EQ.5) STOP
         GO TO 2000
         END
```

DATE:JULY 21
DECLINATION ANGLE= 20DEGREES 17.MINUTES

HOUR	DNI	ALT	SOLAR HEAT GAIN FACTORS								
			N	NE	E	SE	S	SW	W	NW	HORIZONTAL
5	1.27	2: 7	.54	1.25	1.21	.42	.08	.08	.08	.08	.14
6	135.91	12:52	35.79	123.29	135.78	68.06	10.74	10.74	10.74	10.74	30.97
7	207.34	24: 8	29.54	161.57	203.44	127.17	20.80	19.51	19.51	19.51	87.04
8	241.07	35:36	28.35	147.50	215.66	160.80	30.02	26.09	26.09	26.09	144.55
9	259.16	46:58	32.27	104.82	193.63	171.22	53.17	31.18	31.18	31.18	193.00
10	269.27	57:41	34.90	55.50	146.50	159.81	82.00	36.13	34.90	34.90	230.48
11	274.48	66:29	37.18	39.55	81.27	127.88	103.19	42.97	37.18	37.18	253.79
12	276.10	70:17	37.95	37.95	41.00	81.10	110.75	81.10	41.00	37.95	261.43
13	274.48	66:29	37.18	37.18	37.18	42.97	103.19	127.88	81.27	39.55	253.79
14	269.27	57:41	34.90	34.90	34.90	36.13	82.00	159.81	146.50	55.50	230.48
15	259.16	46:58	32.27	31.18	31.18	31.18	53.17	171.22	193.63	104.82	193.00
16	241.07	35:36	28.35	26.09	26.09	26.09	30.02	160.80	215.66	147.50	144.55
17	207.34	24: 8	29.54	19.51	19.51	19.51	20.80	127.17	203.44	161.57	87.04
18	135.91	12:52	35.79	10.74	10.74	10.74	10.74	68.06	135.78	123.29	30.97
19	1.27	2: 7	.54	.08	.08	.08	.08	.42	1.21	1.25	.14

DATE:JULY 22

DECLINATION ANGLE= 20DEGREES 5.MINUTES

HOUR	DNI	ALT	SOLAR HEAT GAIN FACTORS								
			N	NE	E	SE	S	SW	W	NW	HORIZONTAL
6	134.67	12:45	35.07	122.00	134.69	67.83	10.61	10.61	10.61	10.61	30.41
7	206.84	24: 0	29.09	160.90	203.18	127.47	20.74	19.43	19.43	19.43	86.40
8	240.81	35:29	28.25	146.95	215.69	161.35	30.14	26.03	26.03	26.03	143.99
9	259.01	46:50	32.19	104.25	193.73	171.89	53.78	31.13	31.13	31.13	192.51
10	269.16	57:32	34.86	55.06	146.60	160.55	82.87	36.11	34.86	34.86	230.03
11	274.40	66:18	37.14	39.48	81.31	128.64	104.17	43.13	37.14	37.14	253.39
12	276.02	70: 5	37.91	37.91	40.96	81.72	111.76	81.72	40.96	37.91	261.05
13	274.40	66:18	37.14	37.14	37.14	43.13	104.17	128.64	81.31	39.48	253.39
14	269.16	57:32	34.86	34.86	34.86	36.11	82.87	160.55	146.60	55.06	230.03
15	259.01	46:50	32.19	31.13	31.13	31.13	53.78	171.89	193.73	104.25	192.51
16	240.81	35:29	28.25	26.03	26.03	26.03	30.14	161.35	215.69	146.95	143.99
17	206.84	24: 0	29.09	19.43	19.43	19.43	20.74	127.47	203.18	160.90	86.40
18	134.67	12:45	35.07	10.61	10.61	10.61	10.61	67.83	134.69	122.00	30.41

DATE:JULY 23

DECLINATION ANGLE= 19DEGREES 52.MINUTES

HOUR	DNI	ALT	SOLAR HEAT GAIN FACTORS N	NE	E	SE	S	SW	W	NW	HORIZONTAL
6	133.38	12:37	34.33	120.66	133.54	67.58	10.49	10.49	10.49	10.49	29.85
7	206.33	23:53	28.63	160.20	202.91	127.78	20.68	19.35	19.35	19.35	85.74
8	240.55	35:21	28.15	146.39	215.71	161.91	30.27	25.96	25.96	25.96	143.41
9	258.85	46:42	32.10	103.66	193.83	172.57	54.40	31.08	31.08	31.08	192.01
10	269.05	57:23	34.81	54.61	146.70	161.30	83.77	36.08	34.81	34.81	229.57
11	274.31	66: 7	37.10	39.41	81.34	129.42	105.17	43.30	37.10	37.10	252.98
12	275.94	69:52	37.87	37.87	40.92	82.36	112.79	82.36	40.92	37.87	260.66
13	274.31	66: 7	37.10	37.10	37.10	43.30	105.17	129.42	81.34	39.41	252.98
14	269.05	57:23	34.81	34.81	34.81	36.08	83.77	161.30	146.70	54.61	229.57
15	258.85	46:42	32.10	31.08	31.08	31.08	54.40	172.57	193.83	103.66	192.01
16	240.55	35:21	28.15	25.96	25.96	25.96	30.27	161.91	215.71	146.39	143.41
17	206.33	23:53	28.63	19.35	19.35	19.35	20.68	127.78	202.91	160.20	85.74
18	133.38	12:37	34.33	10.49	10.49	10.49	10.49	67.58	133.54	120.66	29.85

DATE:JULY 24

DECLINATION ANGLE= 19DEGREES 39.MINUTES

HOUR	DNI	ALT	SOLAR HEAT GAIN FACTORS								
			N	NE	E	SE	S	SW	W	NW	HORIZONTAL
6	132.03	12:29	33.58	119.27	132.34	67.30	10.36	10.36	10.36	10.36	29.27
7	205.79	23:45	28.17	159.48	202.61	128.08	20.61	19.27	19.27	19.27	85.06
8	240.28	35:14	28.05	145.81	215.72	162.47	30.42	25.90	25.90	25.90	142.81
9	258.69	46:34	32.02	103.05	193.92	173.27	55.06	31.03	31.03	31.03	191.48
10	268.94	57:14	34.76	54.15	146.81	162.07	84.69	36.06	34.76	34.76	229.09
11	274.22	65:55	37.05	39.34	81.38	130.21	106.21	43.49	37.05	37.05	252.55
12	275.85	69:39	37.83	37.83	40.88	83.03	113.85	83.03	40.88	37.83	260.25
13	274.22	65:55	37.05	37.05	37.05	43.49	106.21	130.21	81.38	39.34	252.55
14	268.94	57:14	34.76	34.76	34.76	36.06	84.69	162.07	146.81	54.15	229.09
15	258.69	46:34	32.02	31.03	31.03	31.03	55.06	173.27	193.92	103.05	191.48
16	240.28	35:14	28.05	25.90	25.90	25.90	30.42	162.47	215.72	145.81	142.81
17	205.79	23:45	28.17	19.27	19.27	19.27	20.61	128.08	202.61	159.48	85.06
18	132.03	12:29	33.58	10.36	10.36	10.36	10.36	67.30	132.34	119.27	29.27

Input data for calculation of the heat gain by the exterior walls:

A(I),I = 1,9

1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0

DO(I),I = 1,4

1.0000 -.94420 .05025 -.00008

BO(I),I = 1,4

.00055 .00735 .00482 .00021

CO(I),I = 1,1

.01293

SHGF(I,J),J = 1,9 and I = 1,24

0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	2.	1.	0.	0.	0.	0.	0.	0.
37.	125.	137.	68.	10.	10.	10.	10.	31.
30.	163.	204.	127.	20.	19.	19.	19.	88.
28.	148.	216.	160.	29.	26.	26.	26.	145.
32.	106.	194.	170.	52.	31.	31.	31.	194.
35.	56.	146.	159.	80.	36.	35.	35.	231.
37.	39.	81.	127.	102.	42.	37.	37.	255.
38.	38.	41.	80.	109.	80.	41.	38.	262.
37.	39.	81.	127.	102.	42.	37.	37.	255.
35.	56.	146.	159.	80.	36.	35.	35.	231.
32.	106.	194.	170.	52.	31.	31.	31.	194.

28.	148.	216.	160.	29.	26.	26.	26.	145.
30.	163.	204.	127.	20.	19.	19.	19.	88.
37.	125.	137.	68.	10.	10.	10.	10.	31.
0.	2.	1.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.

TO(J),J = 1,24

<u>July 21</u> 67.,65.,64.,65.,66.,70.,73.,77.,80.,81.,82.,83.,
87.,90.,92.,95.,91.,86.,80.,78.,75.,73.,70.,69.

<u>July 22</u> 67.,65.,65.,65.,66.22,91.27,100.87,102.44,98.08,
90.57,88.82,89.55,93.82,99.57,110.08,120.44,118.87,
107.27,80.22,87.,75.,73.,70.,69.

<u>July 23</u> 67.,65.,64.,65.,66.21,93.42,108.10,114.20,113.40,
106.27,96.02,90.07,101.02,115.27,125.40,132.40,
126.10,109.42,80.21,87.,75.,73.,70.,69.

<u>July 24</u> 67.,65.,64.,65.,66.02,81.72,94.94,104.74,109.54,
108.57,104.06,96.99,109.06,117.57,121.54,122.74,112.94,
97.74,74.80,80.07,78.,75.,73.,70.,69.

```
      PARAMETER IB=4     ,ID=4     ,IC=1       ,NMAX=24
      DIMENSION SHGF(200,9),TO(100),TSAT(400,9),DO(ID),CO(IC),BO(IB),
     1A(9),QE(400,9)
      READ (5,2)(A(I),I=1,9)
      READ (5,3)(DO(I),I=1,ID)
      READ (5,3)(BO(I),I=1,IB)
      READ (5,3)(CO(I),I=1,IC)
      READ (5,1)((SHGF(I,J),J=1,9),I=1,NMAX)
      KKKK=1
 2000 CONTINUE
      READ (5,2)(TO(J),J=1,NMAX)
    1 FORMAT(9F5.0)
    2 FORMAT(F5.2)
    3 FORMAT(5F10.5)
      WRITE(6,10)
   10 FORMAT(1H1,30X,'SOL - AIR TEMPERATURE',//)
      IF(KKKK.EQ.1) WRITE(6,1001)
      IF(KKKK.EQ.2)WRITE(6,1002)
      IF(KKKK.EQ.3)WRITE(6,1003)
      IF(KKKK.EQ.4)WRITE(6,1004  )
 1001 FORMAT(    '      DATE: JULY 21       ',/)
 1002 FORMAT(    '      DATE: JULY 22       ',/)
 1003 FORMAT(    '      DATE: JULY 23       ',/)
 1004 FORMAT(    '      DATE: JULY 24       ',/)
      DO 4 I=1,NMAX
      DO 4 J=1,9
      TSAT(I,J)=TO(I)+.1725*SHGF(I,J)
      IF (J.EQ.9)TSAT(I,J)=TSAT(I,J)-7.
      TSAT(I+24,J)=TSAT(I,J)
      TR=75.
    4 CONTINUE
      WRITE(6,5)
    5 FORMAT(2X,'TIME      N        NE        E        SE        S        SW
     ' W        NW  HORIZONTAL',/)
      WRITE(6,6)(I,(TSAT(I,J),J=1,9),I=1,NMAX)
    6 FORMAT(2X,I3,F10.3,8F8.3)
```

```
      CC=0
      DO 100 I=1,IC
  100 CC=CC+CO(I)
      DO 7 J=1,9
      DO 7 I=1,NMAX
      F1=0.
      DO 8 K=1,IB
    8 F1=F1+BO(K)*TSAT(I+25-K,J)
      F2=0.
      IDD=ID-1
      DO 9 K=1,IDD
    9 F2=F2+QE(I+24-K,J)*DO(K+1)/A(J)
      QE(I,J)=A(J)*(F1-F2-CC*TR)
      QE(I+24,J)=QE(I,J)
    7 CONTINUE
      WRITE(6,107)
  107 FORMAT(1H1,32X,'HEAT  GAIN',//)
      WRITE(6,108)(J,J=1,9)
  108 FORMAT(2X,'WALL',1X,9('NO=',I1,3X),/)
      WRITE(6,1000)
 1000 FORMAT(2X,'TIME',9(3X,'Q'3X))
      DO 2001 I=1,NMAX
      WRITE(6,99)I,(QE(I,J),J=1,9)
   99 FORMAT(3X,I2,9(1X,F6.3))
 2001 CONTINUE
      KKKK=KKKK+1
      IF(KKKK.EQ.5) STOP
      GO TO 2000
      END
```

SOL - AIR TEMPERATURE

DATE: JULY 21

TIME	N	NE	E	SE	S	SW	W	NW	HORIZONTAL
1	67.000	67.000	67.000	67.000	67.000	67.000	67.000	67.000	60.000
2	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
3	64.000	64.000	64.000	64.000	64.000	64.000	64.000	64.000	57.000
4	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
5	66.000	66.345	66.172	66.000	66.000	66.000	66.000	66.000	59.000
6	76.382	91.562	93.632	81.730	71.725	71.725	71.725	71.725	68.347
7	78.175	101.117	108.190	94.907	76.450	76.277	76.277	76.277	81.180
8	81.830	102.530	114.260	104.600	82.002	81.485	81.485	81.485	95.012
9	85.520	98.285	113.465	109.325	88.970	85.347	85.347	85.347	106.465
10	87.037	90.660	106.185	108.427	94.800	87.210	87.037	87.037	113.847
11	88.382	88.727	95.972	103.907	99.595	89.245	88.382	88.382	118.987
12	89.555	89.555	90.072	96.800	101.802	96.800	90.072	89.555	121.195
13	93.382	93.727	100.972	108.907	104.595	94.245	93.382	93.382	123.987
14	96.037	99.660	115.185	117.427	103.800	96.210	96.037	96.037	122.847
15	97.520	110.285	125.465	121.325	100.970	97.347	97.347	97.347	118.465
16	99.830	120.530	132.260	122.600	100.002	99.485	99.485	99.485	113.012
17	96.175	119.117	126.190	112.907	94.450	94.277	94.277	94.277	99.180
18	92.382	107.562	109.632	97.730	87.725	87.725	87.725	87.725	84.347
19	80.000	80.345	80.172	80.000	80.000	80.000	80.000	80.000	73.000
20	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	71.000
21	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	68.000
22	73.000	73.000	73.000	73.000	73.000	73.000	73.000	73.000	66.000
23	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	63.000
24	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000	62.000

HEAT GAIN

WALL TIME	NO=1 Q	NO=2 Q	NO=3 Q	NO=4 Q	NO=5 Q	NO=6 Q	NO=7 Q	NO=8 Q	NO=9 Q
1	-.073	-.073	-.073	-.073	-.073	-.073	-.073	-.073	-.164
2	-.163	-.163	-.163	-.163	-.163	-.163	-.163	-.163	-.339
3	-.270	-.270	-.270	-.270	-.270	-.270	-.270	-.270	-.522
4	-.383	-.383	-.383	-.383	-.383	-.383	-.383	-.383	-.703
5	-.481	-.481	-.481	-.481	-.481	-.481	-.481	-.481	-.861
6	-.551	-.540	-.540	-.548	-.554	-.554	-.554	-.554	-.985
7	-.530	-.394	-.376	-.479	-.568	-.568	-.568	-.568	-1.013
8	-.441	-.059	.026	-.231	-.511	-.513	-.513	-.513	-.886
9	-.318	.308	.517	.139	-.389	-.397	-.397	-.397	-.593
10	-.161	.612	.983	.561	-.194	-.235	-.235	-.235	-.165
11	.012	.803	1.336	.956	.064	-.053	-.055	-.055	.340
12	.186	.917	1.533	1.267	.364	.139	.127	.127	.871
13	.359	1.012	1.613	1.474	.677	.376	.310	.306	1.392
14	.550	1.134	1.736	1.711	.988	.610	.509	.503	1.889
15	.759	1.314	2.010	2.047	1.274	.822	.724	.718	2.335
16	.974	1.591	2.412	2.426	1.503	1.030	.941	.935	2.691
17	1.189	1.970	2.878	2.790	1.680	1.234	1.155	1.150	2.936
18	1.363	2.349	3.278	3.043	1.787	1.385	1.314	1.310	3.013
19	1.465	2.584	3.467	3.096	1.798	1.440	1.377	1.374	2.889
20	1.442	2.529	3.326	2.926	1.712	1.394	1.338	1.335	2.610
21	1.337	2.313	3.021	2.659	1.575	1.293	1.243	1.240	2.279
22	1.205	2.071	2.700	2.378	1.416	1.165	1.121	1.119	1.944
23	1.054	1.823	2.381	2.095	1.241	1.018	.980	.977	1.614
24	.885	1.568	2.063	1.809	1.051	.853	.819	.817	1.287

SOL - AIR TEMPERATURE

DATE: JULY 22

TIME	N	NE	E	SE	S	SW	W	NW	HORIZONTAL
1	67.000	67.000	67.000	67.000	67.000	67.000	67.000	67.000	60.000
2	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
3	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
4	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
5	66.220	66.565	66.392	66.220	66.220	66.220	66.220	66.220	59.220
6	97.653	112.832	114.903	103.000	92.995	92.995	92.995	92.995	89.618
7	105.975	128.917	135.990	122.707	104.250	104.077	104.077	104.077	108.980
8	107.230	127.930	139.660	130.000	107.402	106.885	106.885	106.885	120.412
9	103.600	116.365	131.545	127.405	107.050	103.427	103.427	103.427	124.545
10	96.607	100.230	115.755	117.997	104.370	96.780	96.607	96.607	123.417
11	95.202	95.547	102.792	110.727	106.415	96.065	95.202	95.202	125.807
12	96.105	96.105	96.622	103.350	108.352	103.350	96.622	96.105	127.745
13	100.202	100.547	107.792	115.727	111.415	101.065	100.202	100.202	130.807
14	105.607	109.230	124.755	126.997	113.370	105.780	105.607	105.607	132.417
15	115.520	128.285	143.465	139.325	118.970	115.347	115.347	115.347	136.465
16	125.230	145.930	157.660	148.000	125.402	124.885	124.885	124.885	138.412
17	123.975	146.917	153.990	140.707	122.250	122.077	122.077	122.077	126.980
18	113.582	128.762	130.832	118.930	108.925	108.925	108.925	108.925	105.547
19	80.220	80.565	80.392	80.220	80.220	80.220	80.220	80.220	73.220
20	87.000	87.000	87.000	87.000	87.000	87.000	87.000	87.000	80.000
21	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	68.000
22	73.000	73.000	73.000	73.000	73.000	73.000	73.000	73.000	66.000
23	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	63.000
24	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000	62.000

HEAT GAIN

WALL	NO=1	NO=2	NO=3	NO=4	NO=5	NO=6	NO=7	NO=8	NO=9
TIME	Q	Q	Q	Q	Q	Q	Q	Q	Q
1	.710	1.316	1.755	1.530	.857	.682	.651	.649	.970
2	.531	1.069	1.460	1.260	.662	.506	.479	.478	.667
3	.347	.825	1.171	.994	.464	.325	.301	.300	.372
4	.172	.596	.904	.746	.276	.153	.131	.130	.098
5	.017	.393	.666	.526	.108	-.001	-.020	-.021	-.145
6	-.095	.250	.492	.360	-.016	-.113	-.130	-.131	-.335
7	.048	.481	.714	.501	.083	-.003	-.018	-.019	-.263
8	.403	1.048	1.324	.969	.397	.319	.306	.305	.110
9	.785	1.645	2.023	1.559	.771	.695	.683	.683	.645
10	1.105	2.085	2.606	2.107	1.122	1.021	1.011	1.010	1.221
11	1.318	2.293	2.960	2.511	1.415	1.245	1.234	1.233	1.752
12	1.460	2.353	3.089	2.762	1.678	1.405	1.384	1.384	2.239
13	1.583	2.381	3.087	2.894	1.936	1.593	1.520	1.516	2.700
14	1.729	2.442	3.139	3.066	2.200	1.783	1.676	1.670	3.144
15	1.927	2.595	3.374	3.369	2.468	1.984	1.880	1.873	3.569
16	2.211	2.929	3.824	3.800	2.764	2.262	2.167	2.162	3.987
17	2.588	3.460	4.433	4.312	3.102	2.629	2.546	2.541	4.388
18	2.965	4.031	5.018	4.753	3.409	2.983	2.908	2.904	4.661
19	3.203	4.392	5.327	4.929	3.553	3.174	3.108	3.104	4.668
20	3.116	4.267	5.110	4.686	3.402	3.066	3.007	3.004	4.321
21	2.903	3.935	4.683	4.300	3.155	2.856	2.804	2.801	3.877
22	2.643	3.559	4.223	3.883	2.866	2.600	2.554	2.552	3.411
23	2.335	3.148	3.738	3.436	2.533	2.297	2.256	2.254	2.921
24	2.022	2.744	3.268	2.999	2.198	1.989	1.952	1.950	2.447

SOL - AIR TEMPERATURE

DATE: JULY 23

TIME	N	NE	E	SE	S	SW	W	NW	HORIZONTAL
1	67.000	67.000	67.000	67.000	67.000	67.000	67.000	67.000	60.000
2	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
3	64.000	64.000	64.000	64.000	64.000	64.000	64.000	64.000	57.000
4	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
5	66.210	66.555	66.382	66.210	66.210	66.210	66.210	66.210	59.210
6	99.802	114.982	117.052	105.150	95.145	95.145	95.145	95.145	91.767
7	113.275	136.217	143.290	130.007	111.550	111.377	111.377	111.377	116.280
8	119.030	139.730	151.460	141.800	119.202	118.685	118.685	118.685	132.212
9	118.920	131.685	146.865	142.725	122.370	118.747	118.747	118.747	139.865
10	112.237	115.860	131.385	133.627	120.000	112.410	112.237	112.237	139.047
11	102.403	102.748	109.993	117.927	113.615	103.265	102.403	102.403	133.007
12	96.625	96.625	97.142	103.870	108.872	103.870	97.142	96.625	128.265
13	107.382	107.727	114.972	122.907	118.595	108.245	107.382	107.382	137.987
14	121.237	124.860	140.385	142.627	129.000	121.410	121.237	121.237	148.047
15	130.920	143.685	158.865	154.725	134.370	130.747	130.747	130.747	151.865
16	137.230	157.930	169.660	160.000	137.402	136.885	136.885	136.885	150.412
17	131.275	154.217	161.290	148.007	129.550	129.377	129.377	129.377	134.280
18	115.782	130.962	133.032	121.130	111.125	111.125	111.125	111.125	107.747
19	80.210	80.555	80.382	80.210	80.210	80.210	80.210	80.210	73.210
20	87.000	87.000	87.000	87.000	87.000	87.000	87.000	87.000	80.000
21	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	68.000
22	73.000	73.000	73.000	73.000	73.000	73.000	73.000	73.000	66.000
23	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	63.000
24	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000	62.000

HEAT GAIN

WALL	NO=1	NO=2	NO=3	NO=4	NO=5	NO=6	NO=7	NO=8	NO=9
TIME	Q	Q	Q	Q	Q	Q	Q	Q	Q
1	1.719	2.360	2.825	2.587	1.875	1.690	1.657	1.655	2.000
2	1.428	1.996	2.409	2.198	1.566	1.401	1.373	1.371	1.581
3	1.142	1.647	2.014	1.826	1.265	1.119	1.094	1.092	1.182
4	.871	1.319	1.644	1.478	.980	.850	.827	.826	.810
5	.631	1.030	1.318	1.170	.728	.613	.593	.592	.482
6	.451	.815	1.071	.932	.534	.432	.414	.413	.222
7	.553	1.003	1.248	1.029	.592	.501	.485	.484	.252
8	.923	1.583	1.870	1.509	.920	.838	.824	.823	.639
9	1.381	2.254	2.642	2.173	1.371	1.291	1.278	1.278	1.249
10	1.821	2.813	3.343	2.840	1.842	1.737	1.726	1.725	1.944
11	2.160	3.145	3.820	3.367	2.260	2.086	2.074	2.074	2.600
12	2.350	3.253	3.995	3.665	2.570	2.295	2.274	2.273	3.135
13	2.427	3.233	3.946	3.749	2.782	2.437	2.364	2.359	3.549
14	2.547	3.268	3.969	3.894	3.019	2.601	2.493	2.487	3.966
15	2.815	3.490	4.274	4.266	3.358	2.872	2.767	2.761	4.460
16	3.205	3.929	4.828	4.801	3.759	3.255	3.161	3.155	4.984
17	3.652	4.529	5.506	5.383	4.167	3.693	3.609	3.604	5.455
18	4.035	5.106	6.096	5.830	4.480	4.053	3.978	3.974	5.734
19	4.214	5.408	6.345	5.946	4.565	4.185	4.119	4.115	5.681
20	4.029	5.184	6.029	5.604	4.316	3.979	3.920	3.916	5.237
21	3.715	4.750	5.501	5.116	3.967	3.667	3.615	3.612	4.691
22	3.363	4.283	4.949	4.608	3.587	3.321	3.275	3.272	4.133
23	2.975	3.790	4.382	4.079	3.173	2.937	2.896	2.893	3.562
24	2.590	3.314	3.840	3.570	2.766	2.557	2.520	2.518	3.016

SOL - AIR TEMPERATURE

DATE: JULY 24

TIME	N	NE	E	SE	S	SW	W	NW	HORIZONTAL
1	67.000	67.000	67.000	67.000	67.000	67.000	67.000	67.000	60.000
2	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
3	64.000	64.000	64.000	64.000	64.000	64.000	64.000	64.000	57.000
4	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
5	66.020	66.365	66.193	66.020	66.020	66.020	66.020	66.020	59.020
6	88.102	103.282	105.352	93.450	83.445	83.445	83.445	83.445	80.068
7	100.115	123.057	130.130	116.847	98.390	98.217	98.217	98.217	103.120
8	109.530	130.230	141.960	132.300	109.702	109.185	109.185	109.185	122.712
9	115.020	127.785	142.965	138.825	118.470	114.847	114.847	114.847	135.965
10	114.537	118.160	133.685	135.927	122.300	114.710	114.537	114.537	141.347
11	110.382	110.727	117.972	125.907	121.595	111.245	110.382	110.382	140.987
12	103.545	103.545	104.062	110.790	115.792	110.790	104.062	103.545	135.185
13	115.382	115.727	122.972	130.907	126.595	116.245	115.382	115.382	145.987
14	123.537	127.160	142.685	144.927	131.300	123.710	123.537	123.537	150.347
15	127.020	139.785	154.965	150.825	130.470	126.847	126.847	126.847	147.965
16	127.530	148.230	159.960	150.300	127.702	127.185	127.185	127.185	140.712
17	118.075	141.017	148.090	134.807	116.350	116.177	116.177	116.177	121.080
18	104.122	119.302	121.372	109.470	99.465	99.465	99.465	99.465	96.087
19	80.070	80.415	80.242	80.070	80.070	80.070	80.070	80.070	73.070
20	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	71.000
21	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	68.000
22	73.000	73.000	73.000	73.000	73.000	73.000	73.000	73.000	66.000
23	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	63.000
24	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000	62.000

HEAT GAIN

WALL TIME	NO=1 Q	NO=2 Q	NO=3 Q	NO=4 Q	NO=5 Q	NO=6 Q	NO=7 Q	NO=8 Q	NO=9 Q
1	2.223	2.866	3.333	3.094	2.380	2.194	2.161	2.159	2.505
2	1.875	2.446	2.860	2.648	2.014	1.849	1.820	1.818	2.029
3	1.540	2.046	2.414	2.225	1.663	1.516	1.491	1.489	1.581
4	1.223	1.673	1.999	1.832	1.333	1.203	1.180	1.179	1.164
5	.944	1.344	1.633	1.485	1.042	.926	.906	.905	.796
6	.721	1.086	1.343	1.204	.805	.702	.684	.683	.493
7	.698	1.149	1.395	1.175	.737	.646	.630	.629	.397
8	.888	1.549	1.836	1.475	.885	.803	.789	.788	.604
9	1.203	2.077	2.466	1.996	1.193	1.113	1.100	1.099	1.072
10	1.579	2.571	3.102	2.598	1.599	1.495	1.483	1.483	1.702
11	1.941	2.927	3.602	3.149	2.040	1.866	1.855	1.854	2.381
12	2.228	3.132	3.874	3.543	2.448	2.173	2.152	2.151	3.013
13	2.417	3.224	3.937	3.740	2.772	2.427	2.353	2.349	3.539
14	2.639	3.360	4.062	3.986	3.111	2.693	2.585	2.578	4.058
15	2.956	3.632	4.416	4.408	3.500	3.013	2.909	2.902	4.602
16	3.313	4.037	4.937	4.910	3.867	3.363	3.269	3.263	5.092
17	3.650	4.527	5.504	5.381	4.165	3.691	3.607	3.602	5.453
18	3.877	4.948	5.938	5.672	4.322	3.895	3.820	3.816	5.576
19	3.913	5.107	6.045	5.646	4.265	3.884	3.818	3.814	5.381
20	3.688	4.843	5.688	5.264	3.975	3.637	3.579	3.575	4.896
21	3.339	4.374	5.125	4.740	3.591	3.291	3.239	3.236	4.314
22	2.982	3.901	4.568	4.226	3.206	2.940	2.893	2.891	3.752
23	2.631	3.447	4.039	3.736	2.830	2.594	2.553	2.550	3.219
24	2.285	3.010	3.535	3.266	2.462	2.252	2.215	2.213	2.711

<u>Input data for calculation of the heat gain by interior partitions with constant TB</u>

U = .490

A = 1.0

TB = 78.

TR = 75.

```
      READ(5,1)U,A,TB,TRC
    1 FORMAT(F10.3)
      QPT=U*A*(TB-TRC)
      WRITE(6,2)QPT
    2 FORMAT(2X,'HEAT GIAN=',F6.2)
      STOP
      END
```

```
HEAT GIAN=  1.47
```

<u>Input data for calculation of the heat gain by interior partitions</u>

A(I),I = 1,9

1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0

DO(I), I = 1,4

.0036 .0458 .0309 .0017

BO(I),I = 1,4

1.000 -.9441 .1435 -.0009

CO(I),I = 1,1

.0800

TB(I,J),J = 1, 9 and I = 1,24

```
*   75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,
    75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.
    75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,
    75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.
    75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,
    75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.
    75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,
    75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.
    75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,
    75.,75.,75.,75.,75.,75.,75.,75.,75.,75.,75.
    67.,65.,64.,65.,66.,70.,73.,77.,80.,81.,82.,83.,87.,
    90.,92.,95.,91.,86.,80.,78.,75.,73.,70.,69.
    67.,65.,64.,65.,66.,70.,73.,77.,80.,81.,82.,83.,87.,
    90.,92.,95.,91.,86.,80.,78.,75.,73.,70.,69.
```

*These data repeated for four days.

67.,65.,64.,65.,66.,70.,73.,77.,80.,81.,82.,83.,87.,
90.,92.,95.,91.,86.,80.,78.,75.,73.,70.,69.
67.,65.,64.,65.,66.,70.,73.,77.,80.,81.,82.,83.,87.,
90.,92.,95.,91.,86.,80.,78.,75.,73.,70.,69.

```
      PARAMETER IB=4,ID=4,IC=1,NMAX=24,NWALL=9
      DIMENSION TB(NMAX,9),TSAT(400,9),DO(40),CO(IC),BO(IB), A(9),
     1QE(400,9)
      READ(5,10)(A(I),I=1,9)
      READ (5,3)(DO(I),I=1,ID)
      READ (5,3)(BO(I),I=1,IB)
      READ (5,3)(CO(I),I=1,IC)
      KKKK=1
 2000 CONTINUE
      READ(5,2)((TB(I,J),J=1,NWALL),I=1,NMAX)
   10 FORMAT(F5.0)
    3 FORMAT(5F10.4)
    2 FORMAT(24F3.0)
      IF(KKKK.EQ.1) WRITE(6,1001)
      IF(KKKK.EQ.2) WRITE(6,1002)
      IF(KKKK.EQ.3) WRITE(6,1003)
      IF(KKKK.EQ.4) WRITE(6,1004)
 1001 FORMAT(1H1,'      JULY 21.  '/)
 1002 FORMAT(1H1,'      JULY 22.  '/)
 1003 FORMAT(1H1,'      JULY 23.  '/)
 1004 FORMAT(1H1,'      JULY 24.  '/)
      DO 4 I=1,NMAX
      DO 4 J=1,NWALL
      TSAT(I,J)=TB(I,J)
      TSAT(I+24,J)=TB(I,J)
      TR=75.
    4 CONTINUE
      CC=0
      DO 100 I=1,IC
  100 CC=CC+CO(I)
      DO 7 J=1,NWALL
      DO 7 I=1,NMAX
      F1=0.
      DO 8 K=1,IB
    8 F1=F1+BO(K)*TSAT(I+25-K,J)
      F2=0.
```

```
      IDD=ID-1
      DO 9 K=1,IDD
    9 F2=F2+QE(I+24-K,J)*DO(K+1)/A(J)
      QE(I,J)=A(J)*(F1-F2-CC*TR)
      QE(I+24,J)=QE(I,J)
    7 CONTINUE
      WRITE(6,108)(J,J=1,9)
  108 FORMAT(2X,'WALL',2X,9('NO=',I1,4X),/)
      WRITE(6,1000)
 1000 FORMAT(2X,'TIME',9(4X,'Q'3X))
      DO 1111 I=1,NMAX
      WRITE(6,99)I,(QE(I,J),J=1,9)
   99 FORMAT(3X,I2,1X,9(1X,F7.2))
 1111 CONTINUE
      KKKK=KKKK+1
      IF(KKKK.EQ.5) STOP
      GO TO 2000
      END
```

JULY 21.

WALL	NO=1	NO=2	NO=3	NO=4	NO=5	NO=6	NO=7	NO=8	NO=9
TIME	Q	Q	Q	Q	Q	Q	Q	Q	Q
1	-10.28	-5.93	-.77	5.04	7.07	10.05	12.51	15.77	17.00
2	12.23	11.45	10.50	9.37	8.99	8.42	8.02	7.43	7.23
3	8.63	8.53	8.42	8.30	8.25	8.19	8.14	8.06	8.04
4	8.13	8.15	8.18	8.21	8.22	8.24	8.25	8.26	8.27
5	8.23	8.23	8.23	8.24	8.24	8.24	8.24	8.25	8.25
6	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
7	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
8	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
9	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
10	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
11	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
12	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
13	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
14	8.24	8.24	8.24	.24	-1.76	-2.76	-1.76	-.76	3.24
15	6.24	10.24	13.24	22.16	25.14	27.13	30.14	32.15	30.19
16	30.22	22.26	14.29	6.04	2.73	-1.42	-7.22	-13.03	-15.38
17	-19.87	-17.28	-12.86	-5.93	-2.83	4.28	9.91	17.37	21.76
18	25.28	27.71	28.97	31.09	32.81	30.40	30.20	21.82	13.72
19	6.46	3.06	-1.21	-7.13	-12.99	-15.40	-19.96	-17.44	-13.05
20	-6.01	-2.90	4.23	9.88	17.35	21.75	25.28	27.72	28.98
21	31.07	32.80	30.40	30.19	21.82	13.72	6.46	3.06	-1.20
22	-7.13	-12.99	-15.40	-19.96	-17.44	-13.05	-6.01	-2.90	4.23
23	9.88	17.35	21.76	25.28	27.72	28.98	31.07	32.80	30.40
24	30.19	21.82	13.72	6.46	3.06	-1.20	-7.13	-12.99	-15.40

JULY 22.

WALL	NO=1	NO=2	NO=3	NO=4	NO=5	NO=6	NO=7	NO=8	NO=9
TIME	Q	Q	Q	Q	Q	Q	Q	Q	Q
1	-11.96	-7.44	-2.05	3.99	6.10	9.23	11.88	15.35	16.76
2	11.36	10.82	10.09	9.17	8.89	8.45	8.21	7.80	7.67
3	8.67	8.57	8.46	8.33	8.28	8.22	8.16	8.08	8.05
4	8.16	8.17	8.19	8.22	8.22	8.23	8.24	8.25	8.25
5	8.23	8.23	8.23	8.24	8.24	8.24	8.24	8.25	8.25
6	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
7	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
8	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
9	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
10	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
11	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
12	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
13	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
14	8.24	8.24	8.24	.24	-1.76	-2.76	-1.76	-.76	3.24
15	6.24	10.24	13.24	22.16	25.14	27.13	30.14	32.15	30.19
16	30.22	22.26	14.29	6.04	2.73	-1.42	-7.22	-13.03	-15.38
17	-19.87	-17.28	-12.86	-5.93	-2.83	4.28	9.91	17.37	21.76
18	25.28	27.71	28.97	31.09	32.81	30.40	30.20	21.82	13.72
19	6.46	3.06	-1.21	-7.13	-12.99	-15.40	-19.96	-17.44	-13.05
20	-6.01	-2.90	4.23	9.88	17.35	21.75	25.28	27.72	28.98
21	31.07	32.80	30.40	30.19	21.82	13.72	6.46	3.06	-1.20
22	-7.13	-12.99	-15.40	-19.96	-17.44	-13.05	-6.01	-2.90	4.23
23	9.88	17.35	21.76	25.28	27.72	28.98	31.07	32.80	30.40
24	30.19	21.82	13.72	6.46	3.06	-1.20	-7.13	-12.99	-15.40

JULY 23.

WALL	NO=1	NO=2	NO=3	NO=4	NO=5	NO=6	NO=7	NO=8	NO=9
TIME	Q	Q	Q	Q	Q	Q	Q	Q	Q
1	-11.96	-7.44	-2.05	3.99	6.10	9.23	11.88	15.35	16.76
2	11.36	10.82	10.09	9.17	8.89	8.45	8.21	7.80	7.67
3	8.67	8.57	8.46	8.33	8.28	8.22	8.16	8.08	8.05
4	8.16	8.17	8.19	8.22	8.22	8.23	8.24	8.25	8.25
5	8.23	8.23	8.23	8.24	8.24	8.24	8.24	8.25	8.25
6	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
7	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
8	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
9	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
10	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
11	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
12	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
13	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
14	8.24	8.24	8.24	.24	-1.76	-2.76	-1.76	-.76	3.24
15	6.24	10.24	13.24	22.16	25.14	27.13	30.14	32.15	30.19
16	30.22	22.26	14.29	6.04	2.73	-1.42	-7.22	-13.03	-15.38
17	-19.87	-17.28	-12.86	-5.93	-2.83	4.28	9.91	17.37	21.76
18	25.28	27.71	28.97	31.09	32.81	30.40	30.20	21.82	13.72
19	6.46	3.06	-1.21	-7.13	-12.99	-15.40	-19.96	-17.44	-13.05
20	-6.01	-2.90	4.23	9.88	17.35	21.75	25.28	27.72	28.98
21	31.07	32.80	30.40	30.19	21.82	13.72	6.46	3.06	-1.20
22	-7.13	-12.99	-15.40	-19.96	-17.44	-13.05	-6.01	-2.90	4.23
23	9.88	17.35	21.76	25.28	27.72	28.98	31.07	32.80	30.40
24	30.19	21.82	13.72	6.46	3.06	-1.20	-7.13	-12.99	-15.40

JULY 24.

WALL	NO=1	NO=2	NO=3	NO=4	NO=5	NO=6	NO=7	NO=8	NO=9
TIME	Q	Q	Q	Q	Q	Q	Q	Q	Q
1	-11.96	-7.44	-2.05	3.99	6.10	9.23	11.88	15.35	16.76
2	11.36	10.82	10.09	9.17	8.89	8.45	8.21	7.80	7.67
3	8.67	8.57	8.46	8.33	8.28	8.22	8.16	8.08	8.05
4	8.16	8.17	8.19	8.22	8.22	8.23	8.24	8.25	8.25
5	8.23	8.23	8.23	8.24	8.24	8.24	8.24	8.25	8.25
6	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
7	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
8	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
9	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
10	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
11	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
12	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
13	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24	8.24
14	8.24	8.24	8.24	.24	-1.76	-2.76	-1.76	-.76	3.24
15	6.24	10.24	13.24	22.16	25.14	27.13	30.14	32.15	30.19
16	30.22	22.26	14.29	6.04	2.73	-1.42	-7.22	-13.03	-15.38
17	-19.87	-17.28	-12.86	-5.93	-2.83	4.28	9.91	17.37	21.76
18	25.28	27.71	28.97	31.09	32.81	30.40	30.20	21.82	13.72
19	6.46	3.06	-1.21	-7.13	-12.99	-15.40	-19.96	-17.44	-13.05
20	-6.01	-2.90	4.23	9.88	17.35	21.75	25.28	27.72	28.98
21	31.07	32.80	30.40	30.19	21.82	13.72	6.46	3.06	-1.20
22	-7.13	-12.99	-15.40	-19.96	-17.44	-13.05	-6.01	-2.90	4.23
23	9.88	17.35	21.76	25.28	27.72	28.98	31.07	32.80	30.40
24	30.19	21.82	13.72	6.46	3.06	-1.20	-7.13	-12.99	-15.40

<u>Input data for calculation of the solar heat gain through glass</u>

RGO = .035

RO2 = .07

ALP1 = .13

ALP2 = .13

TAUI = .12

RO3 = .70

ALP3 = .18

HO = 4.0

HI = 1.46

HS = .549

TAUO = .80

RGI = .035

TO = 105.

TI = 75.

TSI = 249.6

SHGF = 216.

```
      READ(5,1)RGO,RO2,ALP1,ALP2,TAUI,RO3,ALP3,HO,HI,HS,TAUO,RGI
    1 FORMAT(8F10.3)
      READ(5,2)TO,TI,TSI,SHGF
    2 FORMAT(4F10.2)
      ALPO=ALP1+ALP2*TAUO*RO3/(1.-RO2*RO3)
      ALPI=ALP3*TAUO/(1.-RO2*RO3)
      Z1=TSI*ALPO
      Z2=TSI*ALPI
      X=RGO+RGI+(1./HO)+(1./HI)+(1./HS)
      U=1./X
      Y=(Z1/HO)+Z2*(HO+HS)/(HO*HS)+TO-TI
      QRCI=U*Y
      TGO=TO+(Z1+Z2-QRCI)*((1./HO)+RGO*.5)
      TGI=TI+QRCI*((1./HI)+RGI*.5)
      TAU=TAUO*TAUI/(1.-RO2*RO3)
      F=TAU+U*ALPO/HO+ALPI*U*(HO+HS)/(HO*HS)
      SC=1.15*F
      QA=SC*(SHGF)+U*(TO-TI)
      WRITE(6,3)U
    3 FORMAT(1H1,2X,'THE OVERALL HEAT TRANSFER COEFFICIENT=',F6.2/)
      WRITE(6,4)QRCI
    4 FORMAT(2X,'THE INWARD RADIATION AND CONVECTION GAIN FOR DOUBLE
     -GLAZED UNIT =',F6.2/)
      WRITE(6,5)F
    5 FORMAT(2X,'SOLAR HEAT GAIN COEFFICIENT FOR DOUBLE GLAZING GLASS=',
     'F6.2/)
      WRITE (6,6)QA
    6 FORMAT(2X,'THE SOLAR HEAT GAIN =',F6.2/)
      WRITE(6,7)TO
    7 FORMAT(2X,'OUTDOOR AIR TEMPERATURE USED IN THESE
     'CALCULATIONS=',F6.2/)
      WRITE(6,8)TI
    8 FORMAT(2X,'INDOOR AIR TEMPERATURE=',F6.2)
      STOP
      END
```

THE OVERALL HEAT TRANSFER COEFFICIENT= .35

THE INWARD RADIATION AND CONVECTION GAIN FOR DOUBLE GLAZED UNIT = 42.87

SOLAR HEAT GAIN COEFFICIENT FOR DOUBLE GLAZING GLASS= .23

THE SOLAR HEAT GAIN = 67.79

OUTDOOR AIR TEMPERATURE USED IN THESE CALCULATIONS=105.00

INDOOR AIR TEMPERATURE= 75.00

Input data for calculation of the cooling load

T(1) = -0.00885	AA(1) = 0.01154
T(2) = 2.71235	AA(2) = 0.77674
T(3) = -0.62062	AA(3) = -3.94657
T(4) = -7.07329	AA(4) = 8.57881
T(5) = 9.75995	AA(5) = -8.38135
T(6) = -3.89922	AA(6) = 3.01188

GR = .2

A = 344.

B = .207

C = .136

DAY = 202.

BL = 0.	BM = 0.	BN = -1.
BL = 0.	BM = .707	BN = -.707
BL = 0.	BM = 1.	BN = 0.
BL = 0.	BM = .707	BN = .707
BL = 0.	BM = 0.	BN = 1.
BL = 0.	BM = -.707	BN = .707
BL = 0.	BM = -1.	BN = 0.
BL = 0.	BM = -.707	BN = -.707
BL = 1.	BM = 0.	BN = 0.

V(1) = .1944	V(2) = -.3348	V(3) = .1615	V(4) = -.0150
W(1) = 1.0000	W(2) = -2.2908	W(3) = 1.7252	W(4) = -.4277

```
      DIMENSION T(6),AA(6),V(4),W(4),BL(10),BM(10),BN(10),
     'SHGF (9,24),SHG(9,48),QR(9,48)
      READ(5,1) (T(I),AA(I),I=1,6)
    1 FORMAT(2F10.5)
      READ(5,2) GR,A,B,C,DAY
    2 FORMAT(5F10.5)
      READ(5,3) (BL(I),BM(I),BN(I),I=1,9)
    3 FORMAT(3F10.3)
      READ(5,2)(V(I),I=1,4)
      READ(5,2)(W(I),I=1,4)
      KKKK=1
      IV=4
      IW1=3
 1000 CONTINUE
      AAAA=KKKK-1
      DAY=202.+AAAA
      CALL HGFAC(T,AA,DAY,BL,BM,BN,GR,A,B,C,SHGF)
      DO 4 I=1,24
      DO 4 J=1,9
      SHG(J,I)=SHGF(J,I)*3.32
    4 SHG(J,I+24)=SHG(J,I)
      DO 5 I=1,24
      DO 5 J=1,9
      QR(J,I)=0.
      DO 6 K=1,IV
    6 QR(J,I)=QR(J,I)+V(K)*SHG(J,I+25-K)
      DO 7 K=1,IW1
    7 QR(J,I)=QR(J,I)-W(K+1)*QR(J,I+24-K)
    5 QR(J,I+24)=QR(J,I)
      WRITE (6,8)
    8 FORMAT(1H1)
      IF (KKKK.EQ.1) WRITE (6,1001)
      IF (KKKK.EQ.2) WRITE (6,1002)
      IF (KKKK.EQ.3) WRITE (6,1003)
      IF (KKKK.EQ.4) WRITE (6,1004)
 1001 FORMAT(15X,'DATE: JULY 21')
```

```
      1002 FORMAT(15X,'DATE: JULY 22')
      1003 FORMAT(15X,'DATE: JULY 23')
      1004 FORMAT(15X,'DATE: JULY 24')
           WRITE(6,9)
         9 FORMAT(5X,'N', 6X,'NE', 7X,'E', 6X,'SE', 7X,'S', 6X,
          ''SW', 7X,'W', 6X,'NW',4X,'HORIZONTAL')
           WRITE(6,10)((QR(I,J),I=1,9),J=1,24)
        10 FORMAT(2X,9(F7.3,1X))
           KKKK=KKKK+1
           IF(KKKK.EQ.5) STOP
           GO TO 1000
           END
```

```
           SUBROUTINE HGFAC(T,AA,DAY,BL,BM,BN,GR,A,B,C,SHGF)
           DIMENSION T(6),AA(6),SHGF(9,24),AZ1(24),AZ2(24),BITA1(24),BITA2(24
          1),DNI(24)
           DIMENSION   BL(10),BM(10),BN(10)
           NMAX=24
           D=23.5*SIN((DAY-80.)*360./(365.*57.3))
           ID=D
           AI=ID
           SEC=(D-AI)*60.
           SEC=ABS(SEC)
           D=D/57.3
           AL=40.
           AL=AL/57.3
           DO 12 NWALL=1,9
           WL=BL(NWALL)
           WM=BM(NWALL)
           WN=BN(NWALL)
           NBY2=NMAX/2
           DO 12 I=1,NBY2
           AI=ABS(I-12)
```

```
      H=AI*15.
      FF=COS(AI*15./57.3)
      AAA=SIN(AL)*SIN(D)+COS(D)*COS(AL)*COS(AI*15./57.3)
      BB=COS(D)*SIN(AI*15./57.3)
      CC=SQRT(1.-AAA*AAA-BB*BB)
      XXX=ATAN(AAA/SQRT(1.-AAA*AAA))*57.3
      IH=XXX
      AI=IH
      BITA1(I)=IH
      BITA2(I)=ABS((XXX-AI)*60.)
      G=(COS(AL)*SIN(D)-COS(D)*SIN(AL)*COS(H/57.3))/COS(XXX/57.3)
      IF(ABS(G).GE.1.) GO TO 253
      G=ATAN(SQRT(1.-G*G)/G)
      IF(G.LT.0.) G=G+4.*ATAN(1.)
  253 IF(ABS(G).GE.1.) G=0.
      G=G*57.3
      IH=G
      AI=IH
      AI=(G-AI)*60.
      AZ1(I)=G
      AZ2(I)=ABS(AI)
      IF(AAA.LE.0.) GO TO 123
      DNI(I)=A/EXP(B/AAA)
  123 CONTINUE
      GG=SIN(D)*COS(AL)/(COS(D)*SIN(AL))
      IF(FF.LT.GG)    CC=-CC
      THA=WL*AAA+WM*BB+WN*CC
      SUM1=0.
      SUM2=0.
      SUM3=0.
      SUM4=0.
      IF(ABS(THA).LE..0001) GO TO 124
      ZZZZ=1./THA
  124 IF(ABS(THA).LE..0001) ZZZZ=0.
      DO 13 J=1,6
      AJ=J-1
```

```
          ZZZZ=ZZZZ*THA
          SUM1=SUM1+T(J)*ZZZZ
          SUM2=SUM2+AA(J)*ZZZZ
          SUM3=SUM3+T(J)/(AJ+2.)
          SUM4=SUM4+AA(J)/(AJ+2.)
   13     CONTINUE
          DI=0.
          IF(THA.GT.0.) DI=DNI(I)*THA
          F=THA
          IF(F.GT.-.2)Y=.55+.437*F+.313*F*F
          IF(F.LE.-.2)Y=0.45
          DHI=C*DNI(I)
          DVI=DHI
          IF(NWALL.LT.9)  DVI=DNI(I)*(C*Y+.5*GR*(C+AAA))
          SHGT=DI*SUM1+2.*DVI*SUM3
          SHGA=DI*SUM2+2.*DVI*SUM4
          SHGF(NWALL,I)=SHGT+.267*SHGA
          BITA1(24-I)=BITA1(I)
          BITA2(24-I)=BITA2(I)
          DNI(24-I)=DNI(I)
          SHGF(NWALL,24-I)=SHGF(NWALL,I)
   12     CONTINUE
          DO 14 NWALL=2,8
          DO 14 I=1,12
   14     SHGF(10-NWALL,24-I)=SHGF(NWALL,I)
          RETURN
          END
```

DATE: JULY 21

N	NE	E	SE	S	SW	W	NW	HORIZONTAL
.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000
.000	.000	.000	.000	.000	.000	.000	.000	.000
.347	.805	.778	.273	.052	.052	.052	.052	.094
23.299	80.032	88.078	44.083	6.958	6.958	6.958	6.958	20.039
32.344	149.848	181.450	107.166	17.383	16.555	16.555	16.555	67.576
38.668	187.203	249.846	168.460	29.849	26.840	26.840	26.840	133.414
46.122	188.742	284.555	216.443	52.933	36.958	36.958	36.958	206.638
53.165	163.853	283.255	243.751	86.077	47.116	46.319	46.319	279.492
59.851	142.487	247.523	245.725	121.098	58.643	54.451	54.451	344.730
65.386	129.530	205.090	222.315	149.652	91.260	62.930	60.959	396.502
69.280	121.244	178.644	187.808	165.460	141.674	95.107	67.057	430.931
71.197	114.799	160.418	164.460	165.120	194.525	156.942	82.098	444.760
71.620	108.589	146.231	146.785	149.795	237.634	226.027	123.723	436.438
70.157	101.597	133.677	132.266	128.151	262.160	286.166	176.951	406.501
70.732	93.081	121.139	118.619	110.246	260.972	320.846	220.787	356.006
75.484	82.070	107.102	103.999	92.792	227.456	305.462	227.273	292.040
55.889	68.160	90.817	87.453	74.958	167.752	216.816	158.462	233.828
45.179	59.058	79.776	76.346	63.411	133.188	168.257	122.017	196.196
37.868	52.310	71.391	68.009	55.141	109.821	135.923	97.873	169.487
32.681	47.094	64.750	61.482	48.975	93.528	113.767	81.415	149.785
28.860	42.897	59.287	56.168	44.184	81.756	98.088	69.841	134.642
25.926	39.394	54.641	51.687	40.309	72.902	86.562	61.396	122.517

DATE: JULY 22

N	NE	E	SE	S	SW	W	NW	HORIZONTAL
23.581	36.380	50.583	47.800	37.060	65.961	77.734	54.977	112.442
21.635	33.724	46.967	44.353	34.254	60.299	70.688	49.892	103.801
19.967	31.341	43.695	41.246	31.772	55.518	64.848	45.706	96.204
18.502	29.176	40.705	38.412	29.540	51.365	59.849	42.142	89.397
17.423	27.731	38.475	35.992	27.543	47.711	55.496	39.062	83.279
38.769	104.405	122.629	77.282	32.510	51.216	58.403	43.117	97.215
46.650	172.491	213.813	138.405	41.209	57.759	64.420	50.182	139.270
52.119	208.262	280.235	197.923	52.184	65.246	71.436	58.162	200.142
58.719	208.288	313.068	244.243	74.151	72.780	78.543	66.160	268.808
64.968	182.074	309.969	269.973	106.300	80.553	85.116	73.560	337.446
70.894	159.681	272.487	270.438	140.356	89.975	90.656	79.870	398.778
75.708	145.684	228.371	245.501	167.952	120.883	96.721	84.681	446.909
78.922	136.384	200.364	209.283	182.801	169.665	126.697	89.179	477.915
80.196	128.965	180.682	184.327	181.473	220.902	186.502	102.491	488.520
79.992	121.826	165.134	165.214	165.066	262.427	253.667	142.510	477.168
77.943	113.954	151.305	149.389	142.162	285.386	311.958	194.315	444.372
77.744	104.599	137.569	134.538	123.100	282.598	344.741	236.766	391.178
81.689	92.781	122.391	118.787	104.619	247.305	327.118	241.606	324.776
61.783	78.187	105.116	101.269	85.949	186.152	237.055	171.992	264.604
50.810	68.446	93.150	89.260	73.649	150.355	187.342	134.915	225.056
43.192	61.090	83.889	80.073	64.684	125.832	153.832	110.053	196.508
37.694	55.300	76.427	72.750	57.875	108.467	130.545	92.872	175.059
33.566	50.563	70.194	66.691	52.487	95.698	113.787	80.592	158.267
30.337	46.554	64.827	61.513	48.058	85.915	101.241	71.466	144.592

DATE: JULY 23

N	NE	E	SE	S	SW	W	NW	HORIZONTAL
27.708	43.068	60.095	56.975	44.292	78.108	91.452	64.399	133.062
25.494	39.969	55.848	52.920	41.004	71.639	83.504	58.701	123.060
23.574	37.172	51.988	49.245	38.074	66.104	76.818	53.937	114.188
21.872	34.620	48.447	45.880	35.423	61.247	71.029	49.832	106.190
20.483	32.611	45.508	42.896	33.022	56.924	65.922	46.231	98.935
41.182	108.172	128.527	83.589	37.549	59.741	68.061	49.735	111.477
48.792	175.900	219.435	144.556	45.905	65.697	73.417	56.340	152.297
54.229	211.365	285.666	203.980	56.680	72.646	79.825	63.902	212.132
60.735	211.069	318.285	250.200	78.734	79.684	86.370	71.514	279.892
66.897	184.644	314.937	275.811	111.006	87.008	92.420	78.555	347.713
72.720	162.268	277.150	276.127	145.138	96.130	97.472	84.530	408.304
77.426	148.203	232.697	250.932	172.744	127.014	103.079	89.027	455.747
80.530	138.795	204.388	214.181	187.537	175.731	132.677	93.211	486.085
81.695	131.247	184.424	188.710	186.064	226.813	192.152	105.991	496.037
81.362	123.968	168.610	169.183	169.358	268.114	258.983	145.515	484.056
79.189	115.950	154.529	153.008	145.922	290.775	316.904	196.938	450.641
78.649	106.444	140.550	137.846	126.373	287.563	349.165	238.972	396.839
82.182	94.458	125.122	121.799	107.494	251.580	330.564	243.055	329.958
62.375	79.787	107.694	104.095	88.583	190.034	240.363	173.569	269.671
51.483	69.964	95.580	91.912	76.083	153.961	190.603	136.638	229.913
43.886	62.522	86.171	82.556	66.938	129.181	156.964	111.795	201.118
38.382	56.646	78.566	75.073	59.969	111.583	133.523	94.582	179.411
34.234	51.825	72.195	68.862	54.436	98.600	116.601	82.240	162.359
30.975	47.736	66.698	63.542	49.873	88.620	103.889	73.037	148.431

DATE: JULY 24

N	NE	E	SE	S	SW	W	NW	HORIZONTAL
28.315	44.173	61.844	58.871	45.985	80.631	93.937	65.885	136.657
26.066	41.002	57.483	54.690	42.583	73.993	85.832	60.101	126.423
24.112	38.138	53.514	50.898	39.548	68.301	78.997	55.252	117.332
22.376	35.522	49.873	47.424	36.799	63.298	73.066	51.064	109.128
20.892	33.307	46.698	44.288	34.296	58.829	67.816	47.374	101.662
41.101	107.978	128.914	84.726	38.657	61.438	69.750	50.723	113.658
48.604	175.600	219.907	145.884	46.931	67.259	74.971	57.241	154.034
54.161	210.999	286.290	205.540	57.762	74.094	81.266	64.732	213.576
60.717	210.606	319.016	251.967	80.141	81.029	87.710	72.284	281.125
66.926	184.187	315.718	277.743	112.758	88.273	93.667	79.271	348.777
72.773	162.032	277.905	278.175	147.169	97.448	98.632	85.194	409.235
77.488	148.089	233.373	252.970	174.975	128.639	104.157	89.642	456.558
80.592	138.748	205.004	215.912	189.889	177.596	133.727	93.760	486.757
81.750	131.235	184.984	190.129	188.435	228.807	193.200	106.233	496.550
81.382	123.969	169.116	170.380	171.583	270.147	260.003	145.469	484.401
79.175	115.947	154.980	154.037	147.750	292.750	317.835	196.705	450.796
78.376	106.422	140.940	138.735	127.832	289.336	349.830	238.504	396.788
81.566	94.390	125.432	122.550	108.668	252.857	330.471	241.984	329.808
61.962	79.763	108.019	104.815	89.631	191.140	240.436	172.865	269.771
51.209	69.966	95.905	92.596	77.033	154.970	190.829	136.215	230.135
43.694	62.538	86.488	83.202	67.807	130.104	157.259	111.531	201.403
38.242	56.670	78.869	75.680	60.769	112.432	133.851	94.418	179.725
34.127	51.853	72.483	69.431	55.176	99.385	116.939	82.137	162.682
30.891	47.765	66.970	64.076	50.560	89.349	104.225	72.972	148.750

<u>Input data for calculation of cooling load of a one-story office building</u>

TO(I), I = 1,24. These temperatures are the same for all four days.

67.,65.,64.,65.,66.,70.,73.,77.,80.,81.,82.,83.,87.,
90.,92.,95.,91.,86.,80.,78.,75.,73.,70.,69.

TB(I), I = 1,24. These temperatures are the same for all four days.

67.,65.,64.,65.,66.,70.,73.,77.,80.,81.,82.,83.,87.,
90.,92.,95.,91.,86.,80.,78.,75.,73.,70.,69.

V(1) = .1944	V(2) = -.3348	V(3) = .1615	V(4) = -.0150
W(1) = 1.0000	W(2) = -2.2908	W(3) = 1.7252	W(4) = -.4277

T(1) = -0.00885	AA(1) = 0.01154
T(2) = 2.71235	AA(2) = 0.77674
T(3) = -0.62062	AA(3) = -3.94657
T(4) = -7.07329	AA(4) = 8.57881
T(5) = 9.75995	AA(5) = -8.38135
T(6) = -3.89922	AA(6) = 3.01188

DAY = 202.

AL = 40.

GR = .2

A = 344.

B = .2070

C = .136

BL = 0.	BM = 0.	BN = -1.
BL = 0.	BM = .707	BN = -.707

```
BL = 0.        BM = 1.       BN = 0.
BL = 0.        BM = .707     BN = .707
BL = 0.        BM = 0.       BN = 1.
BL = 0.        BM = -.707    BN = .707
BL = 0.        BM = -1.      BN = 0.
BL = 0.        BM = -.707    BN = -.707
BL = 1.        BM = 0.       BN = 0.
AW(I), I = 1,9
     321.,0.,765.,0.,321.,0.,312.,0.,4000.
A(I), I = 1,9
     0.,0.,0.,0.,0.,0.,0.,0.,0.
DX(I), I = 1,6
     1.,-.9694,.0461,-.0003,0.,0.
BX(I), I = 1,6
     .0010,.0083,.0040,.0010,0.,0.
CX(I), I = 1,1
     .0134
DO(I), I = 1,6
     1.0,-1.51622,.64218,-.08370,.00288,-.00001
BO(I), I = 1,6
     .00002,.00199,.00817,.00467,.00044,.00001
CO(I), I = 1,1
     .01530
RGO = .035
RGI = .035
TAUO = .80
```

RO2 = .07

ALP1 = .13

ALP2 = .13

TAUI = .12

RO3 = .7

ALP3 = .18

HO = 4.

HI = 1.46

HS = .549

```
      PARAMETER IB=6,ID=6,IC=1,NMAX=24
      DIMENSION T(6),AA(6),AW(9),AGLASS(9),DO(ID),BO(IB),CO(IC),TO(24),
     -QW1(9,48  ),QW2(9,48  ),QGLASS(9,48  ),TB(24),
     1BL(10),BM(10),BN(10),SHGF(9,24) ,TI(24)
      DIMENSION AX(9),DX(ID),BX(IB),CX(IC)
      DIMENSION V(4),W(4)
      DATA(TO(I),I=1,24)/67.,65.,64.,65.,66.,70.,73.,77.,80.,81.,82.,83.,
     1,87.,90.,92.,95.,91.,86.,80.,78.,75.,73.,70.,69./
      DATA(TB(I),I=1,24)/67.,65.,64.,65.,66.,70.,73.,77.,80.,81.,82.,83.,
     1,87.,90.,92.,95.,91.,86.,80.,78.,75.,73.,70.,69./
      READ(5,1)(V(I),I=1,4)
      READ(5,1)(W(I),I=1,4)
      READ(5,16)(T(I),AA(I),I=1,6)
   16 FORMAT(2F10.5)
      READ(5,1)DAY,AL
      READ(5,1)GR,A,B,C
    1 FORMAT(5F10.4)
      READ(5,125)(BL(I),BM(I),BN(I),I=1,9)
  125 FORMAT(3F10.4)
      KKKK=1
      READ(5,2)(AW(I),I=1,9)
      READ(5,2)(AX(I),I=1,9)
      READ(5,3)(DX(I),I=1,ID)
      READ(5,3)(BX(I),I=1,IB)
      READ(5,3)(CX(I),I=1,IC)
      READ(5,3)(DO(I),I=1,ID)
      READ(5,3)(BO(I),I=1,IB)
      READ(5,3)(CO(I),I=1,IC)
    3 FORMAT(6F10.5)
      READ(5,6)RGO,RGI,TAUO,RO2,ALP1,ALP2,TAUI,RO3,ALP3,HO,HI,HS
    6 FORMAT(12F5.3)
      TR=75.
  555 CONTINUE
      AAAA=KKKK-1
      DAY=DAY+AAAA
    2 FORMAT(9F5.0)
```

```
      SI=45.
      TILT=30./57.3
      CALL TOTINT(AL,TILT,A,DAY,SI,B,C,GR,TI)
      CALL HGFAC(T,AA,DAY,BL,BM,BN,GR,A,B,C,SHGF)
      CALL QEXT(SHGF,TO,DO,CO,BO,AW,QW1,KKKK)
      CALL QWINT(TB,DX,CX,BX,AX,QW2)
      DO 4 J=1,9
      AGLASS(1)=144.
      AGLASS(5)=144.
      AGLASS(7)=312.
      DO 4 I=1,NMAX
      TTT=TO(I)
      TSI=TI(I)
      CALL  GLASS(   RGO,RGI,RO1,TAUO,RO2,ALP1,ALP2,TAUI,RO3,ALP3,HO,HI,
     1HS,TR,TTT,TSI,SHGF,QG)
      QGLASS(J,I)=QG*AGLASS(J)
    4 CONTINUE
      IF(KKKK.EQ.1)WRITE(6,2001)
      IF(KKKK.EQ.2)WRITE(6,2002)
      IF(KKKK.EQ.3)WRITE(6,2003)
      IF(KKKK.EQ.4)WRITE(6,2004)
 2001 FORMAT(1H1,15X,'DATE: JULY21',/)
 2002 FORMAT(1H1,15X,'DATE: JULY22',/)
 2003 FORMAT(1H1,15X,'DATE: JULY23',/)
 2004 FORMAT(1H1,15X,'DATE: JULY24',/)
      WRITE(6,18)
   18 FORMAT(13X,'NORTH WALL',12X,'EAST WALL',12X,'SOUTH WALL',
     ,13X,'WEST WALL',7X,'HORIZONTAL',3X,'QTOTAL',/)
      WRITE (6,19)
   19 FORMAT(10X,4('WALL',6X,'GLASS',7X),/)
      DO 8 I=1,NMAX
      QTOT=QW1(1,I)+QW1(3,I)+QW1(5,I)+QW1(7,I)+QW1(9,I)+QGLASS(1,I)+QGLA
     1SS(3,I)+QGLASS(5,I)+QGLASS(7,I)
      WRITE(6,9) I,(QW1(J,I),QGLASS(J,I),J=1,7,2),QW1(9,I),QTOT
    9 FORMAT(2X,I3,10F11.3)
    8 CONTINUE
```

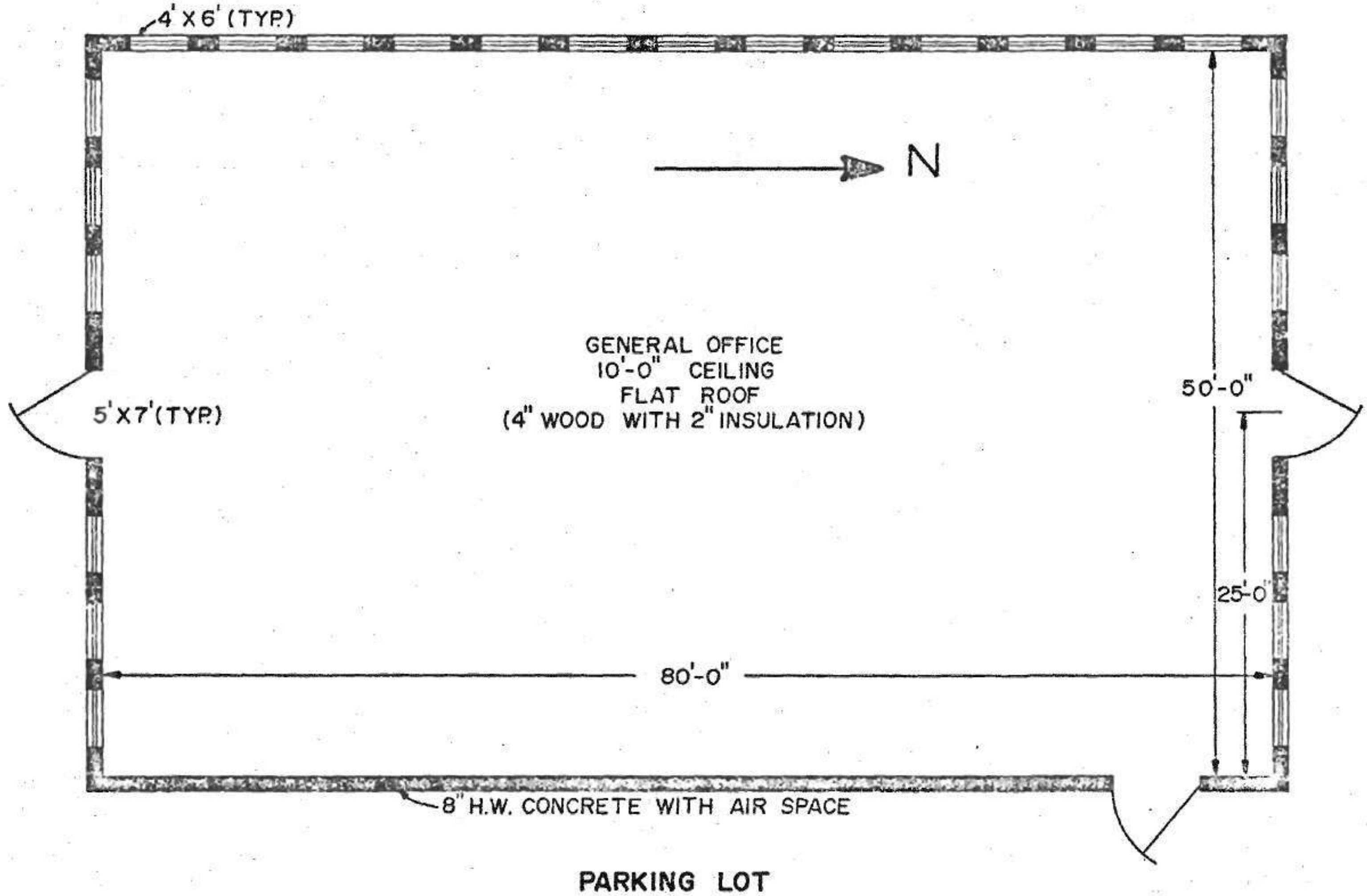


Figure 27. General Office with Flat Roof

```
      KKKK=KKKK+1
      CALL        COOL1(SHGF,V,W,QW1,QGLASS)
      IF(KKKK.EQ.5) STOP
      GO TO 555
      END
```

DECLINATION ANGLE= 20DEGREES 17.MINUTES

SUN RISE IS AT 4: 48.AM.
SUN SET IS AT 7: 12.PM.
NO. OF POSSIBLE HOURS OF SUNSHINE 14: 24.
AZIMUTHAL ANGLE FOR SUNRISE IS 107DEGREES 55.MINUTES.

TIME	HOUR ANGLE	ALTITUTE	ANGLE OF AZIMUTH	ANGLE OF INCIDENT	DIRECT NORMAL INTENSITY	DEFFUSE SOLAR INTENSITY	TOTAL INTENSITY
HOUR= 1	H=165:0	BITA=-28: 6	GAMA= 60:59	AOIN= 82:15	DNI= .00	DSI= .00	TI= .00
HOUR= 2	H=150:0	BITA=-23:32	GAMA= 75:46	AOIN= 90:16	DNI= .00	DSI= .00	TI= .00
HOUR= 3	H=135:0	BITA=-16:34	GAMA= 88:48	AOIN= 97:11	DNI= .00	DSI= .00	TI= .00
HOUR= 4	H=120:0	BITA= -7:50	GAMA=100: 5	AOIN=102:37	DNI= .00	DSI= .00	TI= .00
HOUR= 5	H=105:0	BITA= 2: 7	GAMA=110: 3	AOIN=106: 9	DNI= 1.27	DSI= .16	TI= 1.43
HOUR= 6	H= 90:0	BITA= 12:52	GAMA=119:12	AOIN=107:29	DNI=135.91	DSI=17.25	TI=153.81
HOUR= 7	H= 75:0	BITA= 24: 8	GAMA=128: 6	AOIN=106:27	DNI=207.34	DSI=26.31	TI=235.17
HOUR= 8	H= 60:0	BITA= 35:36	GAMA=137:32	AOIN=103:12	DNI=241.07	DSI=30.59	TI=273.97
HOUR= 9	H= 45:0	BITA= 46:58	GAMA=148:37	AOIN= 98: 0	DNI=259.16	DSI=32.89	TI=295.06
HOUR=10	H= 30:0	BITA= 57:41	GAMA=163:41	AOIN= 91:15	DNI=269.27	DSI=34.17	TI=306.98
HOUR=11	H= 15:0	BITA= 66:29	GAMA=187:32	AOIN= 83:21	DNI=274.48	DSI=34.83	TI=313.18
HOUR=12	H= 0:0	BITA= 70:17	GAMA=224:58	AOIN= 74:41	DNI=276.10	DSI=35.03	TI=315.12
HOUR=13	H= 15:0	BITA= 66:29	GAMA= 97:32	AOIN= 65:36	DNI=274.48	DSI=34.83	TI=313.18
HOUR=14	H= 30:0	BITA= 57:41	GAMA= 73:41	AOIN= 56:27	DNI=269.27	DSI=34.17	TI=306.98
HOUR=15	H= 45:0	BITA= 46:58	GAMA= 58:37	AOIN= 47:41	DNI=259.16	DSI=32.89	TI=295.06
HOUR=16	H= 60:0	BITA= 35:36	GAMA= 47:32	AOIN= 39:57	DNI=241.07	DSI=30.59	TI=273.97
HOUR=17	H= 75:0	BITA= 24: 8	GAMA= 38: 6	AOIN= 34:17	DNI=207.34	DSI=26.31	TI=235.17
HOUR=18	H= 90:0	BITA= 12:52	GAMA= 29:12	AOIN= 31:57	DNI=135.91	DSI=17.25	TI=153.81
HOUR=19	H=105:0	BITA= 2: 7	GAMA= 20: 3	AOIN= 33:45	DNI= 1.27	DSI= .16	TI= 1.43
HOUR=20	H=120:0	BITA= -7:50	GAMA= 10: 5	AOIN= 39: 3	DNI= .00	DSI= .00	TI= .00
HOUR=21	H=135:0	BITA=-16:34	GAMA= -1:11	AOIN= 46:35	DNI= .00	DSI= .00	TI= .00
HOUR=22	H=150:0	BITA=-23:32	GAMA=-14:13	AOIN= 55:15	DNI= .00	DSI= .00	TI= .00
HOUR=23	H=165:0	BITA=-28: 6	GAMA=-29: 0	AOIN= 64:22	DNI= .00	DSI= .00	TI= .00
HOUR=24	H=180:0	BITA=-29:43	GAMA=-44:58	AOIN= 73:29	DNI= .00	DSI= .00	TI= .00

HOUR	DNI	ALT	SOLAR HEAT GAIN FACTORS								
			N	NE	E	SE	S	SW	W	NW	HORIZONTAL
5	1.27	2: 7	.54	1.25	1.21	.42	.08	.08	.08	.08	.14
6	135.91	12:52	35.79	123.29	135.78	68.06	10.74	10.74	10.74	10.74	30.97
7	207.34	24: 8	29.54	161.57	203.44	127.17	20.80	19.51	19.51	19.51	87.04
8	241.07	35:36	28.35	147.50	215.66	160.80	30.02	26.09	26.09	26.09	144.55
9	259.16	46:58	32.27	104.82	193.63	171.22	53.17	31.18	31.18	31.18	193.00
10	269.27	57:41	34.90	55.50	146.50	159.81	82.00	36.13	34.90	34.90	230.48
11	274.48	66:29	37.18	39.55	81.27	127.88	103.19	42.97	37.18	37.18	253.79
12	276.10	70:17	37.95	37.95	41.00	81.10	110.75	81.10	41.00	37.95	261.43
13	274.48	66:29	37.18	37.18	37.18	42.97	103.19	127.88	81.27	39.55	253.79
14	269.27	57:41	34.90	34.90	34.90	36.13	82.00	159.81	146.50	55.50	230.48
15	259.16	46:58	32.27	31.18	31.18	31.18	53.17	171.22	193.63	104.82	193.00
16	241.07	35:36	28.35	26.09	26.09	26.09	30.02	160.80	215.66	147.50	144.55
17	207.34	24: 8	29.54	19.51	19.51	19.51	20.80	127.17	203.44	161.57	87.04
18	135.91	12:52	35.79	10.74	10.74	10.74	10.74	68.06	135.78	123.29	30.97
19	1.27	2: 7	.54	.08	.08	.08	.08	.42	1.21	1.25	.14

DATE: JULY 21

TIME	N	NE	E	SE	S	SW	W	NW	HORIZONTAL
1	67.000	67.000	67.000	67.000	67.000	67.000	67.000	67.000	60.000
2	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
3	64.000	64.000	64.000	64.000	64.000	64.000	64.000	64.000	57.000
4	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
5	66.093	66.215	66.208	66.073	66.014	66.014	66.014	66.014	59.025
6	76.174	91.268	93.423	81.741	71.852	71.852	71.852	71.852	68.342
7	78.096	100.870	108.094	94.937	76.587	76.366	76.366	76.366	81.014
8	81.890	102.444	114.202	104.739	82.178	81.500	81.500	81.500	94.934
9	85.566	98.081	113.402	109.535	89.172	85.379	85.379	85.379	106.293
10	87.020	90.575	106.271	108.567	95.145	87.233	87.020	87.020	113.758
11	88.413	88.822	96.019	104.060	99.800	89.413	88.413	88.413	118.779
12	89.546	89.546	90.073	96.989	102.104	96.989	90.073	89.546	121.096
13	93.413	93.413	93.413	94.413	104.800	109.060	101.019	93.822	123.779
14	96.020	96.020	96.020	96.233	104.145	117.567	115.271	99.575	122.758
15	97.566	97.379	97.379	97.379	101.172	121.535	125.402	110.081	118.293
16	99.890	99.500	99.500	99.500	100.178	122.739	132.202	120.444	112.934
17	96.096	94.366	94.366	94.366	94.587	112.937	126.094	118.870	99.014
18	92.174	87.852	87.852	87.852	87.852	97.741	109.423	107.268	84.342
19	80.093	80.014	80.014	80.014	80.014	80.073	80.208	80.215	73.025
20	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	71.000
21	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	68.000
22	73.000	73.000	73.000	73.000	73.000	73.000	73.000	73.000	66.000
23	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	63.000
24	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000	62.000

DATE: JULY21

	NORTH WALL		EAST WALL		SOUTH WALL		WEST WALL		HORIZONTAL	QTOTAL
	WALL	GLASS	WALL	GLASS	WALL	GLASS	WALL	GLASS		
1	12.679	-407.582	30.217	.000	12.679	-407.582	12.324	-883.094	104.800	-1525.558
2	37.427	-509.477	89.194	.000	37.427	-509.477	36.377	-1103.868	303.551	-1618.847
3	68.736	-560.425	163.811	.000	68.736	-560.425	66.809	-1214.255	545.553	-1421.460
4	101.694	-509.477	242.354	.000	101.694	-509.477	98.843	-1103.868	787.932	-790.306
5	133.412	-458.530	317.945	.000	133.412	-458.530	129.672	-993.481	1007.933	-188.167
6	162.706	-254.739	387.811	.000	162.691	-254.739	158.130	-551.934	1198.881	1008.807
7	191.452	-101.895	464.308	.000	190.583	-101.895	185.240	-220.774	1386.986	1994.004
8	221.307	101.895	560.372	.000	218.955	101.895	212.775	220.774	1620.347	3258.321
9	254.906	254.739	691.042	.000	250.440	254.739	243.192	551.934	1966.084	4467.075
10	294.174	305.686	865.366	.000	287.893	305.686	278.622	662.321	2493.740	5493.489
11	339.326	356.634	1077.495	.000	333.451	356.634	320.031	772.708	3252.170	6808.449
12	389.692	407.582	1308.625	.000	388.341	407.582	367.280	883.094	4255.065	8407.261
13	444.040	611.373	1536.686	.000	452.526	611.373	419.335	1324.641	5476.415	10876.388
14	501.445	764.216	1745.859	.000	525.028	764.216	476.490	1655.802	6867.258	13300.313
15	561.101	866.112	1928.534	.000	603.452	866.112	540.511	1876.575	8362.009	15604.406
16	622.600	1018.955	2086.565	.000	684.558	1018.955	614.216	2207.736	9889.984	18143.568
17	685.914	815.164	2227.499	.000	765.239	815.164	700.723	1766.189	11382.818	19158.709
18	749.694	560.425	2355.380	.000	841.652	560.425	799.494	1214.255	12755.922	19837.246
19	812.024	254.739	2470.171	.000	910.214	254.739	904.871	551.934	13925.049	20083.740
20	868.689	152.843	2566.886	.000	967.527	152.843	1005.043	331.160	14815.988	20860.980
21	916.524	.000	2640.343	.000	1011.601	.000	1090.087	.000	15390.639	21049.195
22	952.468	-101.895	2686.107	.000	1041.317	-101.895	1151.272	-220.774	15646.048	21052.648
23	975.427	-254.739	2704.064	.000	1057.380	-254.739	1186.090	-551.934	15624.322	20485.872
24	986.179	-305.686	2696.924	.000	1061.502	-305.686	1197.846	-662.321	15387.081	20055.839

N	NE	E	SE	S	SW	W	NW	HORIZONTAL
-121.73	.00	-500.64	.00	-135.05	.00	-88.44	.00	-2842.58
-176.74	.00	-744.65	.00	-196.31	.00	-122.68	.00	-4237.22
-202.20	.00	-875.74	.00	-225.18	.00	-133.69	.00	-5012.05
-207.73	.00	-929.37	.00	-232.32	.00	-129.89	.00	-5369.36
-200.21	.00	-930.87	.00	-225.25	.00	-117.03	.00	-5449.89
-184.38	.00	-898.03	.00	-209.17	.00	-98.90	.00	-5350.38
-163.06	.00	-840.62	.00	-187.31	.00	-77.68	.00	-5131.76
-137.88	.00	-763.19	.00	-161.55	.00	-54.45	.00	-4827.15
-109.46	.00	-666.28	.00	-132.67	.00	-29.43	.00	-4447.35
-77.90	.00	-548.78	.00	-100.71	.00	-2.37	.00	-3987.63
-43.27	.00	-411.17	.00	-65.32	.00	27.06	.00	-3436.32
-5.71	.00	-257.07	.00	-26.04	.00	59.09	.00	-2783.00
34.49	.00	-92.62	.00	17.45	.00	93.73	.00	-2024.62
77.02	.00	75.56	.00	65.24	.00	131.10	.00	-1166.58
121.56	.00	241.86	.00	117.00	.00	171.66	.00	-222.79
167.83	.00	402.96	.00	171.98	.00	216.25	.00	786.21
215.70	.00	557.86	.00	229.18	.00	266.03	.00	1835.58
264.79	.00	706.39	.00	287.26	.00	321.68	.00	2893.87
314.55	.00	848.17	.00	344.72	.00	382.63	.00	3925.13
363.79	.00	981.91	.00	399.91	.00	446.39	.00	4891.71
411.19	.00	1105.69	.00	451.37	.00	509.62	.00	5761.11
455.31	.00	1217.39	.00	497.86	.00	568.56	.00	6509.86
494.95	.00	1315.50	.00	538.62	.00	620.29	.00	7128.33
529.41	.00	1399.36	.00	573.36	.00	663.39	.00	7618.99

DECLINATION ANGLE= 20DEGREES 5.MINUTES

SUN RISE IS AT 4: 49.AM.
SUN SET IS AT 7: 11.PM.
NO. OF POSSIBLE HOURS OF SUNSHINE 14: 23.
AZIMUTHAL ANGLE FOR SUNRISE IS 108DEGREES 10.MINUTES.

TIME	HOUR ANGLE	ALTITUTE	ANGLE OF AZIMUTH	ANGLE OF INCIDENT	DIRECT NORMAL INTENSITY	DEFFUSE SOLAR INTENSITY	TOTAL INTENSITY
HOUR= 1	H=165:0	BITA=-28:19	GAMA= 61: 2	AOIN= 82:25	DNI= .00	DSI= .00	TI= .00
HOUR= 2	H=150:0	BITA=-23:43	GAMA= 75:52	AOIN= 90:26	DNI= .00	DSI= .00	TI= .00
HOUR= 3	H=135:0	BITA=-16:44	GAMA= 88:55	AOIN= 97:22	DNI= .00	DSI= .00	TI= .00
HOUR= 4	H=120:0	BITA= -7:59	GAMA=100:14	AOIN=102:49	DNI= .00	DSI= .00	TI= .00
HOUR= 5	H=105:0	BITA= 1:58	GAMA=110:12	AOIN=106:21	DNI= .85	DSI= .11	TI= .96
HOUR= 6	H= 90:0	BITA= 12:45	GAMA=119:22	AOIN=107:41	DNI=134.67	DSI=17.09	TI=152.40
HOUR= 7	H= 75:0	BITA= 24: 0	GAMA=128:17	AOIN=106:40	DNI=206.84	DSI=26.25	TI=234.59
HOUR= 8	H= 60:0	BITA= 35:29	GAMA=137:44	AOIN=103:24	DNI=240.81	DSI=30.56	TI=273.68
HOUR= 9	H= 45:0	BITA= 46:50	GAMA=148:52	AOIN= 98:11	DNI=259.01	DSI=32.87	TI=294.88
HOUR=10	H= 30:0	BITA= 57:32	GAMA=163:57	AOIN= 91:25	DNI=269.16	DSI=34.15	TI=306.85
HOUR=11	H= 15:0	BITA= 66:18	GAMA=187:48	AOIN= 83:31	DNI=274.40	DSI=34.82	TI=313.08
HOUR=12	H= 0:0	BITA= 70: 5	GAMA=224:59	AOIN= 74:51	DNI=276.02	DSI=35.02	TI=315.02
HOUR=13	H= 15:0	BITA= 66:18	GAMA= 97:48	AOIN= 65:45	DNI=274.40	DSI=34.82	TI=313.08
HOUR=14	H= 30:0	BITA= 57:32	GAMA= 73:57	AOIN= 56:37	DNI=269.16	DSI=34.15	TI=306.85
HOUR=15	H= 45:0	BITA= 46:50	GAMA= 58:52	AOIN= 47:51	DNI=259.01	DSI=32.87	TI=294.88
HOUR=16	H= 60:0	BITA= 35:29	GAMA= 47:44	AOIN= 40: 8	DNI=240.81	DSI=30.56	TI=273.68
HOUR=17	H= 75:0	BITA= 24: 0	GAMA= 38:17	AOIN= 34:29	DNI=206.84	DSI=26.25	TI=234.59
HOUR=18	H= 90:0	BITA= 12:45	GAMA= 29:22	AOIN= 32:10	DNI=134.67	DSI=17.09	TI=152.40
HOUR=19	H=105:0	BITA= 1:58	GAMA= 20:12	AOIN= 33:57	DNI= .85	DSI= .11	TI= .96
HOUR=20	H=120:0	BITA= -7:59	GAMA= 10:14	AOIN= 39:14	DNI= .00	DSI= .00	TI= .00
HOUR=21	H=135:0	BITA=-16:44	GAMA= -1: 4	AOIN= 46:45	DNI= .00	DSI= .00	TI= .00
HOUR=22	H=150:0	BITA=-23:43	GAMA=-14: 7	AOIN= 55:24	DNI= .00	DSI= .00	TI= .00
HOUR=23	H=165:0	BITA=-28:19	GAMA=-28:57	AOIN= 64:32	DNI= .00	DSI= .00	TI= .00
HOUR=24	H=180:0	BITA=-29:55	GAMA=-44:58	AOIN= 73:39	DNI= .00	DSI= .00	TI= .00

HOUR	DNI	ALT	N	NE	E	SE	S	SW	W	NW	HORIZONTAL
			SOLAR HEAT GAIN FACTORS								
6	134.67	12:45	35.07	122.00	134.69	67.83	10.61	10.61	10.61	10.61	30.41
7	206.84	24: 0	29.09	160.90	203.18	127.47	20.74	19.43	19.43	19.43	86.40
8	240.81	35:29	28.25	146.95	215.69	161.35	30.14	26.03	26.03	26.03	143.99
9	259.01	46:50	32.19	104.25	193.73	171.89	53.78	31.13	31.13	31.13	192.51
10	269.16	57:32	34.86	55.06	146.60	160.55	82.87	36.11	34.86	34.86	230.03
11	274.40	66:18	37.14	39.48	81.31	128.64	104.17	43.13	37.14	37.14	253.39
12	276.02	70: 5	37.91	37.91	40.96	81.72	111.76	81.72	40.96	37.91	261.05
13	274.40	66:18	37.14	37.14	37.14	43.13	104.17	128.64	81.31	39.48	253.39
14	269.16	57:32	34.86	34.86	34.86	36.11	82.87	160.55	146.60	55.06	230.03
15	259.01	46:50	32.19	31.13	31.13	31.13	53.78	171.89	193.73	104.25	192.51
16	240.81	35:29	28.25	26.03	26.03	26.03	30.14	161.35	215.69	146.95	143.99
17	206.84	24: 0	29.09	19.43	19.43	19.43	20.74	127.47	203.18	160.90	86.40
18	134.67	12:45	35.07	10.61	10.61	10.61	10.61	67.83	134.69	122.00	30.41

DATE: JULY 22

TIME	N	NE	E	SE	S	SW	W	NW	HORIZONTAL
1	67.000	67.000	67.000	67.000	67.000	67.000	67.000	67.000	60.000
2	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
3	64.000	64.000	64.000	64.000	64.000	64.000	64.000	64.000	57.000
4	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
5	66.062	66.145	66.140	66.050	66.009	66.009	66.009	66.009	59.017
6	76.050	91.045	93.234	81.701	71.831	71.831	71.831	71.831	68.246
7	78.018	100.754	108.049	94.989	76.577	76.352	76.352	76.352	80.904
8	81.873	102.350	114.206	104.833	82.199	81.489	81.489	81.489	94.838
9	85.552	97.982	113.419	109.651	89.276	85.370	85.370	85.370	106.209
10	87.013	90.498	106.289	108.694	95.295	87.229	87.013	87.013	113.681
11	88.406	88.810	96.026	104.190	99.969	89.440	88.406	88.406	118.710
12	89.539	89.539	90.066	97.097	102.278	97.097	90.066	89.539	121.031
13	93.406	93.406	93.406	94.440	104.969	109.190	101.026	93.810	123.710
14	96.013	96.013	96.013	96.229	104.295	117.694	115.289	99.498	122.681
15	97.552	97.370	97.370	97.370	101.276	121.651	125.419	109.982	118.209
16	99.873	99.489	99.489	99.489	100.199	122.833	132.206	120.350	112.838
17	96.018	94.352	94.352	94.352	94.577	112.989	126.049	118.754	98.904
18	92.050	87.831	87.831	87.831	87.831	97.701	109.234	107.045	84.246
19	80.062	80.009	80.009	80.009	80.009	80.050	80.140	80.145	73.017
20	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	71.000
21	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	68.000
22	73.000	73.000	73.000	73.000	73.000	73.000	73.000	73.000	66.000
23	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	63.000
24	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000	62.000

DATE: JULY22

	NORTH WALL		EAST WALL		SOUTH WALL		WEST WALL		HORIZONTAL	QTOTAL
	WALL	GLASS	WALL	GLASS	WALL	GLASS	WALL	GLASS		
1	986.749	-407.582	2669.221	.000	1055.985	-407.582	1192.260	-883.094	14996.688	19202.646
2	978.987	-509.477	2624.771	.000	1042.689	-509.477	1174.256	-1103.868	14499.517	18197.398
3	964.518	-560.425	2566.906	.000	1023.182	-560.425	1147.554	-1214.255	13929.354	17296.409
4	944.824	-509.477	2498.747	.000	998.887	-509.477	1114.933	-1103.868	13311.983	16746.552
5	921.446	-458.530	2423.663	.000	971.294	-458.530	1078.676	-993.481	12670.119	16154.658
6	895.920	-254.739	2345.119	.000	941.887	-254.739	1040.711	-551.934	12024.069	16186.294
7	871.656	-101.895	2278.931	.000	913.235	-101.895	1003.802	-220.774	11414.472	16057.532
8	851.126	101.895	2239.861	.000	887.994	101.895	970.625	220.774	10896.280	16270.451
9	837.339	254.739	2243.717	.000	869.147	254.739	944.033	551.934	10538.926	16494.573
10	832.338	305.686	2299.769	.000	859.661	305.686	926.265	662.321	10411.752	16603.479
11	836.330	356.634	2402.081	.000	861.639	356.634	918.230	772.708	10562.164	17066.419
12	848.548	407.582	2531.529	.000	876.195	407.582	919.640	883.094	11001.752	17875.922
13	867.603	611.373	2665.579	.000	903.130	611.373	929.269	1324.641	11702.016	19614.984
14	892.391	764.216	2787.893	.000	941.271	764.216	947.200	1655.802	12611.298	21364.286
15	921.922	866.112	2890.337	.000	988.007	866.112	974.984	1876.575	13661.262	23045.311
16	955.602	1018.955	2974.272	.000	1039.879	1018.955	1015.230	2207.736	14778.516	25009.145
17	993.233	815.164	3046.784	.000	1093.558	815.164	1070.852	1766.189	15892.094	25493.036
18	1033.289	560.425	3111.489	.000	1145.000	560.425	1141.108	1214.255	16914.948	25680.939
19	1073.690	254.739	3167.951	.000	1190.444	254.739	1220.126	551.934	17760.616	25474.237
20	1110.089	152.843	3210.819	.000	1226.340	152.843	1295.930	331.160	18353.042	25833.067
21	1139.196	.000	3234.574	.000	1250.578	.000	1358.441	.000	18652.377	25635.166
22	1157.850	-101.895	3234.469	.000	1261.937	-101.895	1398.803	-220.774	18654.123	25282.617
23	1164.870	-254.739	3210.104	.000	1261.027	-254.739	1414.411	-551.934	18398.865	24387.866
24	1160.941	-305.686	3163.919	.000	1249.470	-305.686	1408.469	-662.321	17946.633	23655.739

N	NE	E	SE	S	SW	W	NW	HORIZONTAL
590.26	.00	1386.38	.00	631.57	.00	796.32	.00	7538.49
634.93	.00	1403.79	.00	674.50	.00	881.70	.00	7593.89
668.89	.00	1426.38	.00	706.98	.00	941.02	.00	7655.51
693.42	.00	1448.91	.00	730.20	.00	979.47	.00	7701.51
709.96	.00	1468.54	.00	745.55	.00	1001.55	.00	7721.54
719.97	.00	1484.02	.00	754.41	.00	1011.07	.00	7712.61
725.19	.00	1497.59	.00	758.37	.00	1011.40	.00	7680.62
727.32	.00	1513.36	.00	759.05	.00	1005.48	.00	7639.99
728.14	.00	1537.03	.00	758.18	.00	995.99	.00	7613.54
729.26	.00	1574.13	.00	757.51	.00	985.23	.00	7629.72
731.85	.00	1627.36	.00	758.69	.00	975.02	.00	7716.94
736.65	.00	1695.32	.00	763.06	.00	966.63	.00	7897.42
743.98	.00	1773.45	.00	771.60	.00	960.79	.00	8182.48
753.96	.00	1856.22	.00	784.84	.00	958.13	.00	8572.48
766.56	.00	1938.77	.00	802.75	.00	959.45	.00	9057.48
781.73	.00	2018.26	.00	824.78	.00	965.84	.00	9619.63
799.42	.00	2094.05	.00	850.06	.00	978.63	.00	10235.84
819.38	.00	2166.16	.00	877.33	.00	998.57	.00	10875.76
841.08	.00	2234.36	.00	905.10	.00	1025.15	.00	11504.07
863.36	.00	2297.40	.00	931.77	.00	1055.90	.00	12083.49
884.91	.00	2353.39	.00	955.87	.00	1087.49	.00	12581.64
904.27	.00	2400.19	.00	976.15	.00	1116.15	.00	12975.03
920.25	.00	2436.25	.00	991.83	.00	1138.94	.00	13253.86
932.13	.00	2460.87	.00	1002.61	.00	1154.42	.00	13420.33

DECLINATION ANGLE= 19DEGREES 39.MINUTES

SUN RISE IS AT 4: 50.AM.
SUN SET IS AT 7: 10.PM.
NO. OF POSSIBLE HOURS OF SUNSHINE 14: 19.
AZIMUTHAL ANGLE FOR SUNRISE IS 108DEGREES 40.MINUTES.

TIME	HOUR ANGLE	ALTITUTE	ANGLE OF AZIMUTH	ANGLE OF INCIDENT	DIRECT NORMAL INTENSITY	DEFFUSE SOLAR INTENSITY	TOTAL INTENSITY
HOUR= 1	H=165:0	BITA=-28:44	GAMA= 61: 9	AOIN= 82:45	DNI= .00	DSI= .00	TI= .00
HOUR= 2	H=150:0	BITA=-24: 7	GAMA= 76: 4	AOIN= 90:48	DNI= .00	DSI= .00	TI= .00
HOUR= 3	H=135:0	BITA=-17: 5	GAMA= 89:10	AOIN= 97:46	DNI= .00	DSI= .00	TI= .00
HOUR= 4	H=120:0	BITA= -8:18	GAMA=100:31	AOIN=103:13	DNI= .00	DSI= .00	TI= .00
HOUR= 5	H=105:0	BITA= 1:41	GAMA=110:31	AOIN=106:47	DNI= .30	DSI= .04	TI= .34
HOUR= 6	H= 90:0	BITA= 12:29	GAMA=119:42	AOIN=108: 7	DNI=132.03	DSI=16.75	TI=149.41
HOUR= 7	H= 75:0	BITA= 23:45	GAMA=128:40	AOIN=107: 5	DNI=205.79	DSI=26.11	TI=233.39
HOUR= 8	H= 60:0	BITA= 35:14	GAMA=138:10	AOIN=103:48	DNI=240.28	DSI=30.49	TI=273.07
HOUR= 9	H= 45:0	BITA= 46:34	GAMA=149:22	AOIN= 98:34	DNI=258.69	DSI=32.83	TI=294.50
HOUR=10	H= 30:0	BITA= 57:14	GAMA=164:32	AOIN= 91:47	DNI=268.94	DSI=34.13	TI=306.58
HOUR=11	H= 15:0	BITA= 65:55	GAMA=188:19	AOIN= 83:52	DNI=274.22	DSI=34.80	TI=312.86
HOUR=12	H= 0:0	BITA= 69:39	GAMA=224:58	AOIN= 75:11	DNI=275.85	DSI=35.00	TI=314.82
HOUR=13	H= 15:0	BITA= 65:55	GAMA= 98:19	AOIN= 66: 5	DNI=274.22	DSI=34.80	TI=312.86
HOUR=14	H= 30:0	BITA= 57:14	GAMA= 74:32	AOIN= 56:56	DNI=268.94	DSI=34.13	TI=306.58
HOUR=15	H= 45:0	BITA= 46:34	GAMA= 59:22	AOIN= 48:12	DNI=258.69	DSI=32.83	TI=294.50
HOUR=16	H= 60:0	BITA= 35:14	GAMA= 48:10	AOIN= 40:31	DNI=240.28	DSI=30.49	TI=273.07
HOUR=17	H= 75:0	BITA= 23:45	GAMA= 38:40	AOIN= 34:53	DNI=205.79	DSI=26.11	TI=233.39
HOUR=18	H= 90:0	BITA= 12:29	GAMA= 29:42	AOIN= 32:36	DNI=132.03	DSI=16.75	TI=149.41
HOUR=19	H=105:0	BITA= 1:41	GAMA= 20:31	AOIN= 34:22	DNI= .30	DSI= .04	TI= .34
HOUR=20	H=120:0	BITA= -8:18	GAMA= 10:31	AOIN= 39:37	DNI= .00	DSI= .00	TI= .00
HOUR=21	H=135:0	BITA=-17: 5	GAMA= 0:49	AOIN= 47: 6	DNI= .00	DSI= .00	TI= .00
HOUR=22	H=150:0	BITA=-24: 7	GAMA=-13:55	AOIN= 55:44	DNI= .00	DSI= .00	TI= .00
HOUR=23	H=165:0	BITA=-28:44	GAMA=-28:50	AOIN= 64:51	DNI= .00	DSI= .00	TI= .00
HOUR=24	H=180:0	BITA=-30:21	GAMA=-44:58	AOIN= 73:59	DNI= .00	DSI= .00	TI= .00

HOUR	DNI	ALT	SOLAR HEAT GAIN FACTORS								
			N	NE	E	SE	S	SW	W	NW	HORIZONTAL
6	132.03	12:29	33.58	119.27	132.34	67.30	10.36	10.36	10.36	10.36	29.27
7	205.79	23:45	28.17	159.48	202.61	128.08	20.61	19.27	19.27	19.27	85.06
8	240.28	35:14	28.05	145.81	215.72	162.47	30.42	25.90	25.90	25.90	142.81
9	258.69	46:34	32.02	103.05	193.92	173.27	55.06	31.03	31.03	31.03	191.48
10	268.94	57:14	34.76	54.15	146.81	162.07	84.69	36.06	34.76	34.76	229.09
11	274.22	65:55	37.05	39.34	81.38	130.21	106.21	43.49	37.05	37.05	252.55
12	275.85	69:39	37.83	37.83	40.88	83.03	113.85	83.03	40.88	37.83	260.25
13	274.22	65:55	37.05	37.05	37.05	43.49	106.21	130.21	81.38	39.34	252.55
14	268.94	57:14	34.76	34.76	34.76	36.06	84.69	162.07	146.81	54.15	229.09
15	258.69	46:34	32.02	31.03	31.03	31.03	55.06	173.27	193.92	103.05	191.48
16	240.28	35:14	28.05	25.90	25.90	25.90	30.42	162.47	215.72	145.81	142.81
17	205.79	23:45	28.17	19.27	19.27	19.27	20.61	128.08	202.61	159.48	85.06
18	132.03	12:29	33.58	10.36	10.36	10.36	10.36	67.30	132.34	119.27	29.27

DATE: JULY 23

TIME	N	NE	E	SE	S	SW	W	NW	HORIZONTAL
1	67.000	67.000	67.000	67.000	67.000	67.000	67.000	67.000	60.000
2	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
3	64.000	64.000	64.000	64.000	64.000	64.000	64.000	64.000	57.000
4	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
5	66.022	66.052	66.050	66.018	66.003	66.003	66.003	66.003	59.006
6	75.793	90.575	92.829	81.608	71.786	71.786	71.786	71.786	68.050
7	77.859	100.511	107.951	95.093	76.556	76.324	76.324	76.324	80.673
8	81.838	102.151	114.211	105.027	82.248	81.467	81.467	81.467	94.635
9	85.523	97.776	113.452	109.889	89.497	85.352	85.352	85.352	106.030
10	86.997	90.341	106.324	108.957	95.609	87.220	86.997	86.997	113.518
11	88.392	88.786	96.038	104.461	100.321	89.501	88.392	88.392	118.564
12	89.525	89.525	90.051	97.322	102.640	97.322	90.051	89.525	120.894
13	93.392	93.392	93.392	94.501	105.321	109.461	101.038	93.786	123.564
14	95.997	95.997	95.997	96.220	104.609	117.957	115.324	99.341	122.518
15	97.523	97.352	97.352	97.352	101.497	121.889	125.452	109.776	118.030
16	99.838	99.467	99.467	99.467	100.248	123.027	132.211	120.151	112.635
17	95.859	94.324	94.324	94.324	94.556	113.093	125.951	118.511	98.673
18	91.793	87.786	87.786	87.786	87.786	97.608	108.829	106.575	84.050
19	80.022	80.003	80.003	80.003	80.003	80.018	80.050	80.052	73.006
20	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	71.000
21	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	68.000
22	73.000	73.000	73.000	73.000	73.000	73.000	73.000	73.000	66.000
23	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	63.000
24	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000	62.000

DATE: JULY23

	NORTH WALL		EAST WALL		SOUTH WALL		WEST WALL		HORIZONTAL	QTOTAL
	WALL	GLASS	WALL	GLASS	WALL	GLASS	WALL	GLASS		
1	1147.988	-407.582	3100.192	.000	1229.473	-407.582	1386.580	-883.094	17358.227	22524.202
2	1127.765	-509.477	3022.504	.000	1202.809	-509.477	1353.554	-1103.868	16678.575	21262.385
3	1101.807	-560.425	2933.969	.000	1170.962	-560.425	1313.004	-1214.255	15940.168	20124.806
4	1071.517	-509.477	2837.509	.000	1135.277	-509.477	1267.612	-1103.868	15167.627	19356.720
5	1038.366	-458.530	2736.305	.000	1097.171	-458.530	1219.577	-993.481	14382.618	18563.497
6	1003.814	-254.739	2633.616	.000	1058.059	-254.739	1170.743	-551.934	13604.469	18409.290
7	971.169	-101.895	2544.940	.000	1020.442	-101.895	1123.797	-220.774	12872.493	18108.277
8	942.846	101.895	2484.951	.000	986.917	101.895	1081.347	220.774	12240.574	18161.199
9	921.802	254.739	2469.316	.000	960.425	254.739	1046.184	551.934	11777.136	18236.274
10	910.053	305.686	2507.294	.000	943.924	305.686	1020.494	662.321	11550.771	18206.229
11	907.814	356.634	2593.016	.000	939.517	356.634	1005.140	772.708	11608.593	18540.054
12	914.315	407.582	2707.340	.000	948.322	407.582	999.796	883.094	11962.146	19230.176
13	928.140	611.373	2827.604	.000	970.123	611.373	1003.193	1324.641	12582.825	20859.273
14	948.143	764.216	2937.308	.000	1003.693	764.216	1015.382	1655.802	13418.696	22507.456
15	973.285	866.112	3028.163	.000	1046.339	866.112	1037.882	1876.575	14401.003	24095.470
16	1002.932	1018.955	3101.407	.000	1094.503	1018.955	1073.270	2207.736	15455.848	25973.606
17	1036.847	815.164	3164.042	.000	1144.745	815.164	1124.427	1766.189	16511.705	26378.282
18	1073.449	560.425	3219.612	.000	1192.932	560.425	1190.560	1214.255	17480.990	26492.647
19	1110.602	254.739	3267.617	.000	1235.227	254.739	1265.693	551.934	18276.896	26217.447
20	1143.957	152.843	3302.668	.000	1268.057	152.843	1337.840	331.160	18823.510	26512.878
21	1170.211	.000	3319.202	.000	1289.320	.000	1396.893	.000	19081.006	26256.632
22	1186.225	-101.895	3312.444	.000	1297.830	-101.895	1434.017	-220.774	19045.077	25851.030
23	1190.851	-254.739	3281.966	.000	1294.229	-254.739	1446.661	-551.934	18756.280	24908.576
24	1184.771	-305.686	3230.170	.000	1280.155	-305.686	1438.045	-662.321	18274.224	24133.672

N	NE	E	SE	S	SW	W	NW	HORIZONTAL
998.23	.00	2462.47	.00	1065.87	.00	1293.15	.00	13426.84
1035.04	.00	2459.59	.00	1100.18	.00	1368.64	.00	13374.86
1056.44	.00	2449.34	.00	1119.15	.00	1412.45	.00	13259.04
1065.71	.00	2431.83	.00	1126.06	.00	1432.18	.00	13087.19
1065.58	.00	2407.62	.00	1123.63	.00	1433.88	.00	12868.09
1058.33	.00	2377.69	.00	1114.14	.00	1422.34	.00	12610.97
1046.23	.00	2345.62	.00	1099.69	.00	1401.56	.00	12329.48
1031.31	.00	2316.42	.00	1082.27	.00	1374.89	.00	12042.85
1015.52	.00	2296.29	.00	1063.81	.00	1345.24	.00	11776.83
1000.62	.00	2291.13	.00	1046.22	.00	1315.07	.00	11561.61
987.86	.00	2303.84	.00	1031.19	.00	1286.26	.00	11426.58
978.00	.00	2333.16	.00	1020.16	.00	1260.13	.00	11394.54
971.40	.00	2374.57	.00	1014.09	.00	1237.41	.00	11477.09
968.17	.00	2422.51	.00	1013.53	.00	1218.73	.00	11674.62
968.25	.00	2472.10	.00	1018.43	.00	1204.88	.00	11977.07
971.58	.00	2520.40	.00	1028.21	.00	1196.92	.00	12366.29
978.09	.00	2566.72	.00	1041.93	.00	1196.15	.00	12818.84
987.48	.00	2610.98	.00	1058.29	.00	1203.28	.00	13303.96
999.18	.00	2652.88	.00	1075.75	.00	1217.75	.00	13785.90
1012.02	.00	2691.08	.00	1092.64	.00	1237.05	.00	14227.06
1024.64	.00	2723.64	.00	1107.46	.00	1257.81	.00	14594.75
1035.57	.00	2748.35	.00	1118.95	.00	1276.24	.00	14865.25
1043.59	.00	2763.57	.00	1126.30	.00	1289.37	.00	15028.53
1047.98	.00	2768.56	.00	1129.20	.00	1295.74	.00	15086.47

DECLINATION ANGLE= 18DEGREES 57.MINUTES

SUN RISE IS AT 4: 53.AM.
SUN SET IS AT 7: 7.PM.
NO. OF POSSIBLE HOURS OF SUNSHINE 14: 14.
AZIMUTHAL ANGLE FOR SUNRISE IS 109DEGREES 29.MINUTES.

TIME	HOUR ANGLE	ALTITUTE	ANGLE OF AZIMUTH	ANGLE OF INCIDENT	DIRECT NORMAL INTENSITY	DEFFUSE SOLAR INTENSITY	TOTAL INTENSITY
HOUR= 1	H=165:0	BITA=-29:24	GAMA= 61:20	AOIN= 83:19	DNI= .00	DSI= .00	TI= .00
HOUR= 2	H=150:0	BITA=-24:45	GAMA= 76:23	AOIN= 91:23	DNI= .00	DSI= .00	TI= .00
HOUR= 3	H=135:0	BITA=-17:40	GAMA= 89:35	AOIN= 98:23	DNI= .00	DSI= .00	TI= .00
HOUR= 4	H=120:0	BITA= -8:49	GAMA=100:59	AOIN=103:53	DNI= .00	DSI= .00	TI= .00
HOUR= 5	H=105:0	BITA= 1:13	GAMA=111: 2	AOIN=107:28	DNI= .02	DSI= .00	TI= .02
HOUR= 6	H= 90:0	BITA= 12: 3	GAMA=120:16	AOIN=108:48	DNI=127.67	DSI=16.20	TI=144.46
HOUR= 7	H= 75:0	BITA= 23:21	GAMA=129:17	AOIN=107:46	DNI=204.05	DSI=25.89	TI=231.40
HOUR= 8	H= 60:0	BITA= 34:49	GAMA=138:51	AOIN=104:28	DNI=239.41	DSI=30.38	TI=272.06
HOUR= 9	H= 45:0	BITA= 46: 9	GAMA=150: 9	AOIN= 99:12	DNI=258.16	DSI=32.76	TI=293.88
HOUR=10	H= 30:0	BITA= 56:45	GAMA=165:25	AOIN= 92:23	DNI=268.57	DSI=34.08	TI=306.15
HOUR=11	H= 15:0	BITA= 65:19	GAMA=189: 7	AOIN= 84:25	DNI=273.92	DSI=34.76	TI=312.51
HOUR=12	H= 0:0	BITA= 68:57	GAMA=224:59	AOIN= 75:43	DNI=275.57	DSI=34.97	TI=314.49
HOUR=13	H= 15:0	BITA= 65:19	GAMA= 99: 7	AOIN= 66:37	DNI=273.92	DSI=34.76	TI=312.51
HOUR=14	H= 30:0	BITA= 56:45	GAMA= 75:25	AOIN= 57:28	DNI=268.57	DSI=34.08	TI=306.15
HOUR=15	H= 45:0	BITA= 46: 9	GAMA= 60: 9	AOIN= 48:46	DNI=258.16	DSI=32.76	TI=293.88
HOUR=16	H= 60:0	BITA= 34:49	GAMA= 48:51	AOIN= 41: 7	DNI=239.41	DSI=30.38	TI=272.06
HOUR=17	H= 75:0	BITA= 23:21	GAMA= 39:17	AOIN= 35:33	DNI=204.05	DSI=25.89	TI=231.40
HOUR=18	H= 90:0	BITA= 12: 3	GAMA= 30:16	AOIN= 33:17	DNI=127.67	DSI=16.20	TI=144.46
HOUR=19	H=105:0	BITA= 1:13	GAMA= 21: 2	AOIN= 35: 2	DNI= .02	DSI= .00	TI= .02
HOUR=20	H=120:0	BITA= -8:49	GAMA= 10:59	AOIN= 40:14	DNI= .00	DSI= .00	TI= .00
HOUR=21	H=135:0	BITA=-17:40	GAMA= 0:24	AOIN= 47:40	DNI= .00	DSI= .00	TI= .00
HOUR=22	H=150:0	BITA=-24:45	GAMA=-13:36	AOIN= 56:17	DNI= .00	DSI= .00	TI= .00
HOUR=23	H=165:0	BITA=-29:24	GAMA=-28:39	AOIN= 65:23	DNI= .00	DSI= .00	TI= .00
HOUR=24	H=180:0	BITA=-31: 3	GAMA=-44:58	AOIN= 74:31	DNI= .00	DSI= .00	TI= .00

HOUR	DNI	ALT	SOLAR HEAT GAIN FACTORS								
			N	NE	E	SE	S	SW	W	NW	HORIZONTAL
6	127.67	12: 3	31.24	114.80	128.40	66.29	9.94	9.94	9.94	9.94	27.47
7	204.05	23:21	26.77	157.18	201.62	128.96	20.41	19.00	19.00	19.00	82.91
8	239.41	34:49	27.73	143.94	215.72	164.22	30.98	25.69	25.69	25.69	140.91
9	258.16	46: 9	31.74	101.12	194.20	175.44	57.16	30.85	30.85	30.85	189.80
10	268.57	56:45	34.61	52.72	147.11	164.47	87.62	35.97	34.61	34.61	227.55
11	273.92	65:19	36.92	39.11	81.49	132.70	109.47	44.11	36.92	36.92	251.15
12	275.57	68:57	37.69	37.69	40.74	85.13	117.20	85.13	40.74	37.69	258.93
13	273.92	65:19	36.92	36.92	36.92	44.11	109.47	132.70	81.49	39.11	251.15
14	268.57	56:45	34.61	34.61	34.61	35.97	87.62	164.47	147.11	52.72	227.55
15	258.16	46: 9	31.74	30.85	30.85	30.85	57.16	175.44	194.20	101.12	189.80
16	239.41	34:49	27.73	25.69	25.69	25.69	30.98	164.22	215.72	143.94	140.91
17	204.05	23:21	26.77	19.00	19.00	19.00	20.41	128.96	201.62	157.18	82.91
18	127.67	12: 3	31.24	9.94	9.94	9.94	9.94	66.29	128.40	114.80	27.47

DATE: JULY 24

TIME	N	NE	E	SE	S	SW	W	NW	HORIZONTAL
1	67.000	67.000	67.000	67.000	67.000	67.000	67.000	67.000	60.000
2	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
3	64.000	64.000	64.000	64.000	64.000	64.000	64.000	64.000	57.000
4	65.000	65.000	65.000	65.000	65.000	65.000	65.000	65.000	58.000
5	66.001	66.004	66.003	66.001	66.000	66.000	66.000	66.000	59.000
6	75.388	89.803	92.150	81.435	71.714	71.714	71.714	71.714	67.739
7	77.617	100.113	107.779	95.246	76.521	76.277	76.277	76.277	80.302
8	81.783	101.830	114.211	105.327	82.344	81.432	81.432	81.432	94.306
9	85.476	97.444	113.499	110.264	89.860	85.322	85.322	85.322	105.740
10	86.971	90.095	106.376	109.371	96.115	87.205	86.971	86.971	113.253
11	88.368	88.747	96.056	104.890	100.884	89.608	88.368	88.368	118.324
12	89.502	89.502	90.028	97.684	103.217	97.684	90.028	89.502	120.666
13	93.368	93.368	93.368	94.608	105.884	109.890	101.056	93.747	123.324
14	95.971	95.971	95.971	96.205	105.115	118.371	115.376	99.095	122.253
15	97.476	97.322	97.322	97.322	101.860	122.264	125.499	109.444	117.740
16	99.783	99.432	99.432	99.432	100.344	123.327	132.211	119.830	112.306
17	95.617	94.277	94.277	94.277	94.521	113.246	125.779	118.113	98.302
18	91.388	87.714	87.714	87.714	87.714	97.435	108.150	105.803	83.739
19	80.001	80.000	80.000	80.000	80.000	80.001	80.003	80.004	73.000
20	78.000	78.000	78.000	78.000	78.000	78.000	78.000	78.000	71.000
21	75.000	75.000	75.000	75.000	75.000	75.000	75.000	75.000	68.000
22	73.000	73.000	73.000	73.000	73.000	73.000	73.000	73.000	66.000
23	70.000	70.000	70.000	70.000	70.000	70.000	70.000	70.000	63.000
24	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000	62.000

DATE: JULY24

	NORTH WALL		EAST WALL		SOUTH WALL		WEST WALL		HORIZONTAL	QTOTAL
	WALL	GLASS	WALL	GLASS	WALL	GLASS	WALL	GLASS		
1	1169.884	-407.582	3161.291	.000	1257.816	-407.582	1413.751	-883.094	17659.129	22963.613
2	1147.913	-509.477	3078.864	.000	1228.981	-509.477	1378.551	-1103.868	16955.401	21666.888
3	1120.365	-560.425	2985.967	.000	1195.125	-560.425	1336.026	-1214.255	16195.121	20497.499
4	1088.622	-509.477	2885.487	.000	1157.582	-509.477	1288.830	-1103.868	15402.606	19700.306
5	1054.138	-458.530	2780.579	.000	1117.759	-458.530	1239.142	-993.481	14599.290	18880.369
6	1018.359	-254.739	2674.452	.000	1077.061	-254.739	1188.788	-551.934	13804.310	18701.560
7	984.505	-101.895	2582.282	.000	1037.965	-101.895	1140.430	-220.774	13056.095	18376.714
8	954.980	101.895	2518.827	.000	1003.062	101.895	1096.664	220.774	12407.965	18406.062
9	932.733	254.739	2499.701	.000	975.301	254.739	1060.267	551.934	11927.777	18457.190
10	919.792	305.686	2534.288	.000	957.697	305.686	1033.417	662.321	11683.875	18402.761
11	916.441	356.634	2616.993	.000	952.417	356.634	1016.981	772.708	11723.786	18712.594
12	921.966	407.582	2728.811	.000	960.647	407.582	1010.637	883.094	12059.820	19380.138
13	934.958	611.373	2847.028	.000	982.193	611.373	1013.115	1324.641	12663.989	20988.671
14	954.250	764.216	2955.023	.000	1015.793	764.216	1024.468	1655.802	13484.641	22618.409
15	978.781	866.112	3044.380	.000	1058.669	866.112	1046.219	1876.575	14453.022	24189.870
16	1007.887	1018.955	3116.257	.000	1107.153	1018.955	1080.946	2207.736	15495.049	26052.936
17	1041.312	815.164	3177.613	.000	1157.669	815.164	1131.521	1766.189	16538.878	26443.510
18	1077.425	560.425	3231.978	.000	1205.974	560.425	1197.105	1214.255	17496.595	26544.183
19	1114.035	254.739	3278.828	.000	1248.154	254.739	1271.598	551.934	18281.344	26255.369
20	1146.823	152.843	3312.797	.000	1280.620	152.843	1343.053	331.160	18817.903	26538.042
21	1172.490	.000	3328.326	.000	1301.314	.000	1401.341	.000	19066.885	26270.355
22	1187.960	-101.895	3320.661	.000	1309.130	-101.895	1437.699	-220.774	19024.659	25855.545
23	1192.151	-254.739	3289.391	.000	1304.787	-254.739	1449.686	-551.934	18732.053	24906.659
24	1185.759	-305.686	3236.915	.000	1289.972	-305.686	1440.566	-662.321	18248.292	24127.812

N	NE	E	SE	S	SW	W	NW	HORIZONTAL
1111.11	.00	2762.24	.00	1188.70	.00	1430.71	.00	15053.99
1143.23	.00	2746.95	.00	1217.71	.00	1500.42	.00	14936.18
1159.47	.00	2723.07	.00	1230.99	.00	1537.92	.00	14747.03
1163.40	.00	2691.43	.00	1232.08	.00	1551.13	.00	14498.74
1157.94	.00	2653.10	.00	1223.87	.00	1546.32	.00	14202.83
1145.46	.00	2609.31	.00	1208.73	.00	1528.41	.00	13870.23
1128.28	.00	2563.78	.00	1188.83	.00	1501.47	.00	13515.48
1108.46	.00	2521.58	.00	1166.19	.00	1468.90	.00	13158.23
1087.99	.00	2488.96	.00	1142.76	.00	1433.61	.00	12824.33
1068.60	.00	2471.84	.00	1120.45	.00	1398.08	.00	12543.94
1051.56	.00	2473.20	.00	1101.01	.00	1364.19	.00	12346.45
1037.66	.00	2491.81	.00	1085.85	.00	1333.26	.00	12254.75
1027.25	.00	2523.17	.00	1076.00	.00	1306.02	.00	12280.51
1020.43	.00	2561.72	.00	1071.98	.00	1283.08	.00	12424.19
1017.17	.00	2602.50	.00	1073.72	.00	1265.22	.00	12675.71
1017.36	.00	2642.57	.00	1080.62	.00	1253.50	.00	13016.84
1020.93	.00	2681.16	.00	1091.69	.00	1249.19	.00	13423.99
1027.56	.00	2718.17	.00	1105.58	.00	1253.02	.00	13866.19
1036.64	.00	2753.25	.00	1120.69	.00	1264.36	.00	14307.55
1047.00	.00	2785.05	.00	1135.31	.00	1280.68	.00	14710.44
1057.27	.00	2811.59	.00	1147.94	.00	1298.61	.00	15042.22
1065.97	.00	2830.65	.00	1157.28	.00	1314.33	.00	15279.27
1071.91	.00	2840.59	.00	1162.55	.00	1324.91	.00	15411.67
1074.35	.00	2840.63	.00	1163.45	.00	1328.89	.00	15441.26

```
      SUBROUTINE TOTINT(AL,TILT,A,DAY,SI,BB,C,GR,TI)
      D=23.5*SIN((DAY-80.)*360./(365.*57.3))
      PARAMETER NMAX=24
      DIMENSION H1(NMAX),H2(NMAX),ST(NMAX),
     -BITA1(NMAX),BITA2(NMAX),AZ1(NMAX),AZ2(NMAX),DNI (NMAX),
     -WSAZ1(NMAX),WSAZ2(NMAX),AOIN1(NMAX),AOIN2(NMAX),
     1DSI(NMAX),THI(NMAX),
     -DGI(NMAX),TI(NMAX)
      TILT1=TILT
      WRITE(6,4)TILT1
      NWALL=4
      ID=D
      AI=ID
      SEC=(D-AI)*60.
      SEC=ABS(SEC)
      WRITE(6,5) ID,SEC
      AL=40.
      AL=AL/57.3
      D=D/57.3
      AD=D
      AI=SIN(AL)*SIN(D)/(COS(AL)*COS(D))
      AI=ATAN(SQRT(1.-AI*AI)/AI)
      IF (AI.LT.0.) AI=AI+4.*ATAN(1.)
      HSS=AI
      TMI=4.*AI/60.*57.3
      IH=TMI
      AI=IH
      AI=(TMI-AI)*60.
      AI=ABS(AI)
      WRITE(6,6)IH,AI
      HRS=12.-TMI
      IH=HRS
      AI=IH
      AI=(HRS-AI)*60.
      AI=ABS(AI)
      WRITE(6,7)IH,AI
```

```
      HPSS=2.*HSS/15.*57.3
      HPSS=24.-HPSS
      IH=HPSS
      AI=IH
      AI=(HPSS-AI)*60.
      AI=ABS(AI)
      WRITE(6,8)IH,AI
      G=COS(AL)*SIN(AD)-COS(AD)*SIN(AL)*SIN(HSS)
      G= ATAN(SQRT(1.-G*G)/G)
      IF(G.LT.0.) G=G+4.*ATAN(1.)
      GG=G*57.3
      IH=GG
      AI=IH
      AI=(GG-AI)*60.
      AI=ABS(AI)
      WRITE(6,9)IH,AI
    4 FORMAT(1H1,2X,'THE SOLAR RADIATION DATA FOR          40 DEGREES N
     -LATITUDE ON THE ROOF WITH',F4.0,'SLOPE FACING SE ARE PRINTED
     -BELOW',///)
    5 FORMAT(5X,'DECLINATION ANGLE=',I4,'DEGREES',F4.0,'MINUTES'/)
    6 FORMAT(5X,'SUN RISE IS AT',I4,':',F4.0,'AM.')
    7 FORMAT(5X,'SUN  SET IS AT',I4,':',F4.0,'PM.')
    8 FORMAT(5X,'NO. OF POSSIBLE HOURS OF SUNSHINE',I4,':',F4.0)
    9 FORMAT(5X,'AZIMUTHAL ANGLE FOR SUNRISE IS',I4,'DEGREES',F4.0,
     -'MINUTES.')
      WRITE(6,1111)
 1111 FORMAT(60X,'DIRECT',4X,'DEFFUSE')
      WRITE(6,2222)
 2222 FORMAT(15X,'HOUR',16X,'ANGLE OF',4X,'ANGLE OF',5X,'NORMAL',
     15X,'SOLAR',5X,'TOTAL')
      WRITE(6,3333)
 3333 FORMAT(7X,'TIME',3X,'ANGLE',3X,'ALTITUTE',4X,'AZIMUTH',5X,
     1'INCIDENT',3X,'INTENSITY',2X,'INTENSITY',1X,'INTENSITY')
      DO 10 I=1,NMAX
      IH=I
      AI=IH
```

```
      ST(I)=I
      B=(ST(I)-AI)
      MAN=AI*60.+B
      MAN=ABS(MAN-720.)
      H=MAN/4.
      IH=H
      AI=IH
      AI=(H-AI)*60.
      H1(I)=IH
      AI=ABS(AI)
      H2(I)=AI
      B=COS(AL)*COS(H/57.3)*COS(D)+SIN(AL)*SIN(D)
      B=(ATAN(B/SQRT(1.-B*B)))*57.3
      IH=B
      AI=IH
      BITA1(I)=IH
      BITA2(I)=(B-AI)*60.
      BITA2(I)=ABS(BITA2(I))
      G=(COS(AL)*SIN(D)-COS(D)*SIN(AL)*COS(H/57.3))/COS(B/57.3)
      G=ATAN(SQRT(1.-G*G)/G)
      IF(G.LT.0.) G=G+4.*ATAN(1.)
      G=G*57.3
      IH=G
      AI=IH
      AI=(G-AI)*60.
      AI=ABS(AI)
      AZ1(I)=G
      AZ2(I)=AI
      SI=+(FLOAT(NWALL)-5.)*45.
      IF(ST(I).GT.12.) SI=-(FLOAT(NWALL)-5.)*45.
      ALPHA=G-SI
      IH=ALPHA
      AI=IH
      WSAZ1(I)=IH
      WSAZ2(I)=(ALPHA-AI)*60.
      WSAZ2(I)=ABS(WSAZ2(I))
```

```
      ALP=ALPHA/57.3
      TT=COS(B/57.3)*COS(ALP)*COS(TILT)+SIN(B/57.3)*SIN(TILT)
      TT=ATAN(SQRT(1.-TT*TT)/TT)
      IF(TT.LT.0.) TT=TT+4.*ATAN(1.)
      TT=TT*57.3
      IH=TT
      AI=IH
      AI=(TT-AI)*60.
      AI=ABS(AI)
      AOIN1(I)=IH
      AOIN2(I)=AI
      IF (ABS(B).LT..0001) GO TO 2003
      DNI(I)=A/EXP(BB/SIN(B/57.3))
 2003 IF (ABS(B).LT..0001) DNI(I)=0.
      IF(B.LT.0.) DNI(I)=0.
      FSQ=0.5*(1.-COS(TILT))
      FSS=1.-FSQ
      DSI(I)=C*DNI(I)*FSS
      THI(I)=DNI(I)*(C+SIN(B/57.3))
      DGI(I)=THI(I)*GR*FSQ
      TI(I)=DNI(I)+DSI(I)+DGI(I)
      I1=H1(I)
      I2=H2(I)
      I3=BITA1(I)
      I4=BITA2(I)
      I5=WSAZ1(I)
      I6=WSAZ2(I)
      I7=AOIN1(I)
      I8=AOIN2(I)
      WRITE (6,11) I,I1,I2,I3,I4,I5,I6,I7,I8,DNI(I),DSI(I),TI(I)
   11 FORMAT(5X,'HOUR=',I2,1X,'H=',I3  ,':',I1  ,1X,'BITA=',I3  ,
     -':',I2  ,1X,'GAMA=',I3  ,':',I2  ,1X,'AOIN=',I3        ,
     -':',I2  ,1X,'DNI=',F6.2,1X,'DSI=',F5.2,1X,'TI=',F6.2)
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE HGFAC(T,AA,DAY,BL,BM,BN,GR,A,B,C,SHGF)
      DIMENSION T(6),AA(6),SHGF(9,24),AZ1(24),AZ2(24),BITA1(24),BITA2(24
     1),DNI(24)
      DIMENSION   BL(10),BM(10),BN(10)
      NMAX=24
      D=23.5*SIN((DAY-80.)*360./(365.*57.3))
      ID=D
      AI=ID
      SEC=(D-AI)*60.
      SEC=ABS(SEC)
      D=D/57.3
      AL=40.
      AL=AL/57.3
      DO 12 NWALL=1,9
      WL=BL(NWALL)
      WM=BM(NWALL)
      WN=BN(NWALL)
      NBY2=NMAX/2
      DO 12 I=1,NBY2
      AI=I
      MAN=AI*60.
      MAN=ABS(MAN-720.)
      H=MAN/4.
      AI=ABS(I-12)
      FF=COS(AI*15./57.3)
      AAA=SIN(AL)*SIN(D)+COS(D)*COS(AL)*COS(AI*15./57.3)
      BB=COS(D)*SIN(AI*15./57.3)
      CC=SQRT(1.-AAA*AAA-BB*BB)
      XXX=ATAN(AAA/SQRT(1.-AAA*AAA))*57.3
      IH=XXX
      AI=IH
      BITA1(I)=IH
      BITA2(I)=ABS((XXX-AI)*60.)
      G=(COS(AL)*SIN(D)-COS(D)*SIN(AL)*COS(H/57.3))/COS(XXX/57.3)
      IF(ABS(G).GE.1.) GO TO 253
      G=ATAN(SQRT(1.-G*G)/G)
```

```
      IF(G.LT.0.) G=G+4.*ATAN(1.)
  253 IF(ABS(G).GE.1.) G=0.
      G=G*57.3
      IH=G
      AI=IH
      AI=(G-AI)*60.
      AZ1(I)=G
      AZ2(I)=ABS(AI)
      IF(AAA.LE.0.) GO TO 123
      DNI(I)=A/EXP(B/AAA)
  123 CONTINUE
      GG=SIN(D)*COS(AL)/(COS(D)*SIN(AL))
      IF(FF.LT.GG)     CC=-CC
      THA=WL*AAA+WM*BB+WN*CC
      SUM1=0.
      SUM2=0.
      SUM3=0.
      SUM4=0.
      IF(ABS(THA).LE..0001) GO TO 124
      ZZZZ=1./THA
  124 IF(ABS(THA).LE..0001) ZZZZ=0.
      DO 13 J=1,6
      AJ=J-1
      ZZZZ=ZZZZ*THA
      SUM1=SUM1+T(J)*ZZZZ
      SUM2=SUM2+AA(J)*ZZZZ
      SUM3=SUM3+T(J)/(AJ+2.)
      SUM4=SUM4+AA(J)/(AJ+2.)
   13 CONTINUE
      DI=0.
      IF(THA.GT.0.) DI=DNI(I)*THA
      F=THA
      IF(F.GT.-.2)Y=.55+.437*F+.313*F*F
      IF(F.LE.-.2)Y=0.45
      DHI=C*DNI(I)
      DVI=DHI
```

```
      IF(NWALL.LT.9)  DVI=DNI(I)*(C*Y+.5*GR*(C+AAA))
      SHGT=DI*SUM1+2.*DVI*SUM3
      SHGA=DI*SUM2+2.*DVI*SUM4
      SHGF(NWALL,I)=SHGT+.267*SHGA
      BITA1(24-I)=BITA1(I)
      BITA2(24-I)=BITA2(I)
      DNI(24-I)=DNI(I)
      SHGF(NWALL,24-I)=SHGF(NWALL,I)
   12 CONTINUE
      DO 14 NWALL=2,8
      DO 14 I=1,12
   14 SHGF(10-NWALL,24-I)=SHGF(NWALL,I)
      WRITE(6,2006)
 2006 FORMAT(1H1)
      WRITE (6,18)
   18 FORMAT(2X,'HOUR',3X,'DNI',4X,'ALT',16X,'SOLAR HEAT GAIN FACTORS')
      WRITE (6,19)
   19 FORMAT(24X,'N',5X,'NE',6X,'E',5X,'SE',6X,'S',5X,'SW',6X,'W',5X,
     1'NW',2X,'HORIZONTAL')
      DO 20 I=1,NMAX
      IF(DNI(I).LE.000001) GO TO 20
      I1=BITA1(I)
      I2=BITA2(I)
      WRITE (6,21) I,DNI(I),I1,I2,(SHGF(N,I),N=1,9)
   21 FORMAT(3X,I2,2X,F6.2,1X,I3,':',I2,1X,F6.2,1X,F6.2,1X,
     1F6.2,1X,F6.2,1X,F6.2,1X,F6.2,1X,F6.2,1X,F6.2 ,1X,F6.2)
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE QEXT(SHGF,TO,DO,CO,BO,AW,QW1,KKKK)
      PARAMETER IB=6      ,ID=6      ,IC=1          ,NMAX=24
      DIMENSION SHGF( 9,24),TO( 24),TSAT(400,9),DO(40),CO(IC),BO(IB),
     'AW(9),QW1(9,48)
      IF(J.NE.9) GO TO 101
  101 CONTINUE
      IF(KKKK.EQ.1)WRITE(6,1001)
      IF(KKKK.EQ.2)WRITE(6,1002)
      IF(KKKK.EQ.3)WRITE(6,1003)
      IF(KKKK.EQ.4)WRITE(6,1004)
 1001 FORMAT(1H1,'     DATE: JULY 21        ',/)
 1002 FORMAT(1H1,'     DATE: JULY 22        ',/)
 1003 FORMAT(1H1,'     DATE: JULY 23        ',/)
 1004 FORMAT(1H1,'     DATE: JULY 24        ',/)
      DO 4 I=1,NMAX
      DO 4 J=1,9
      DO(1)=1.
      DO(2)=-2.0606
      DO(3)=1.4613
      DO(4)=-.4365
      DO(5)=.055
      DO(6)=-.0023
      CO(1)=.0013
      BO(1)=0.
      BO(2)=.0006
      BO(3)=.0002
      BO(4)=.0006
      BO(5)=.0004
      BO(6)=.0001
      TSAT(I,J)=TO(I)+.1725*SHGF(J,I)
      IF (J.EQ.9)TSAT(I,J)=TSAT(I,J)-7.
      TSAT(I+24,J)=TSAT(I,J)
      TR=75.
    4 CONTINUE
      WRITE(6,5)
    5 FORMAT(2X,'TIME     N        NE       E        SE       S        SW
```

```
     '   W        NW   HORIZONTAL',/)
      WRITE(6,6)(I,(TSAT(I,J),J=1,9),I=1,NMAX)
    6 FORMAT(2X,I3,F10.3,8F8.3)
      CC=0
      DO 100 I=1,IC
  100 CC=CC+CO(I)
      DO 7 J=1,9
      DO 7 I=1,NMAX
      F1=0.
      DO 8 K=1,IB
    8 F1=F1+BO(K)*TSAT(I+25-K,J)
      F2=0.
      IDD=ID-1
      DO 9 K=1,IDD
    9 F2=F2+QW1(J,I+24-K)*DO(K+1)
      QW1(J,I)=AW(J)*(F1-CC*TR)-F2
      QW1(J,I+24)=QW1(J,I)
    7 CONTINUE
 2001 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE QWINT(TB,DX,CX,BX,AX,QW2)
      PARAMETER ID=6,IB=6,IC=1,NMAX=24 ,NWALL=1
      DIMENSION TB(NMAX)   ,TSAT(400,9),DX(40),CX(IC),BX(IB),AX(9),
     1QW2(9,48)
      DO 4 I=1,NMAX
      DO 4 J=1,NWALL
      TSAT(I,J)=TB(I)
      TSAT(I+24,J)=TSAT(I,J)
      TR=75.
    4 CONTINUE
      CC=0
      DO 100 I=1,IC
  100 CC=CC+CX(I)
      DO 7 J=1,NWALL
      DO 7 I=1,NMAX
      F1=0.
      DO 8 K=1,IB
    8 F1=F1+BX(K)*TSAT(I+25-K,J)
      F2=0.
      DO 9 K=1,ID
    9 F2=F2+QW2(J,I+24-K)*DX(K+1)
      QW2(J,I)=AX(J)*(F1-CC*TR)-F2
      QW2(J,I+24)=QW2(J,I)
    7 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE  GLASS(   RGO,RGI,RO1,TAUO,RO2,ALP1,ALP2,TAUI,RO3,ALP3,
     1HO,HI,HS,TR,TTT,TSI,SHGF,QG)
      ALPO=ALP1+ALP2*TAUO*RO3/(1.-RO2*RO3)
      ALPI=ALP3*TAUO/(1.-RO2*RO3)
      Z1=TSI*ALPO
      Z2=TSI*ALPI
      X=RGO+RGI+(1./HO)+(1./HI)+(1./HS)
      U=1./X
      Y=(Z1/HO)+Z2*(HO+HI)/(HO*HI)+TTT-TR
      QRCI=U*Y
      TGO=TTT+(Z1+Z2-QRCI)*((1./HO)+RGO*.5)
      TGI=TR+QRCI*((1./HI)+RGI*.5)
      TAU=TAUO*TAUI/(1.-RO2*RO3)
      F=TAU+U*ALPO/HO+ALPI*U*(HO+HS)/(HO*HS)
      SC=1.15*F
      QG=SC*SHGF+U*(TTT-TR)
      RETURN
      END
```

```
      SUBROUTINE COOL1(SHGF,V,W,QW1,QGLASS)
      DIMENSION V(4),W(4), SHGF(9,24),QR(9,48),QW1(9,48),QGLASS(9,48)
      IV=4
      IW1=3
      DO 5 I=1,24
      DO 5 J=1,9
      QR(J,I)=0.
      DO 6 K=1,IV
    6 QR(J,I)=QR(J,I)+V(K)*(QW1(J,I+25-K)+QGLASS(J,I+25-K))
      DO 7 K=1,IW1
    7 QR(J,I)=QR(J,I)-W(K+1)*QR(J,I+24-K)
    5 QR(J,I+24)=QR(J,I)
      WRITE (6,8)
    8 FORMAT(1H1)
      WRITE(6,9)
    9 FORMAT(8X,'N', 8X,'NE', 6X,'E', 9X,'SE', 6X,'S', 9X,
     ''SW', 6X,'W', 9X,'NW',2X,'HORIZONTAL')
      WRITE(6,10)((QR(I,J),I=1,9),J=1,24)
   10 FORMAT(2X,9(F9.2))
      RETURN
      END
```

APPENDIX B

DERIVATION OF EQUATIONS

Figure 1A shows a coordinate system with the Z axis coincident with the earth's axis. The xy plane is coincident with the earth's equatorial plane. The vector I_N, representing the noonday sun, lies in the xz plane. The vector $\overline{PN}$ pointing north from point P is perpendicular to $\overline{OP}$ and lies in the plane containing $\overline{OP}$ and the z axis.

In Figure 1A let a_1, b_1, and c_1 be the direction cosines of $\overline{OP}$ with respect to the x, y, and z axes. Also let a_2, b_2, and c_2 be the corresponding direction cosines of I_N. Thus

$$a_1 = \cos\ell \cos h \qquad a_2 = \cos d$$

$$b_1 = \cos\ell \sin h \qquad b_2 = 0$$

$$c_1 = \sin\ell \qquad c_2 = \sin d$$

The sun's zenith angle (ψ) is the angle between the vector $\overline{OP}$ and I_N. By a common equation from analytic geometry, we have

$$\cos\psi = a_1a_2 + b_1b_2 + c_1c_2$$

Thus the sun's zenith angle (ψ) is

$$\cos\psi = \cos\ell \cos h \cos d + \sin\ell \sin d \tag{1A}$$

since

$$\beta + \psi = \pi/2$$

$$\beta = \pi/2 - \psi$$

The altitude angle (β) is

$$\sin\beta = \cos\ell \cos h \cos d + \sin\ell \sin d \tag{2A}$$

By similar methods, we may show that the sun's azimuth (γ) in Figure 1A is given by the relation

$$\cos\gamma = \sec\beta\ (\cos\ell \sin d - \cos d \sin\ell \cos h) \tag{3A}$$

or

$$\sin\gamma = \frac{\cos d \sin h}{\cos\beta} \tag{4A}$$

Equations (1A)-(4A) allow calculation of the sun's zenith and azimuth angles if the declination, hour angle, and latitude are known. In applying these equations, attention

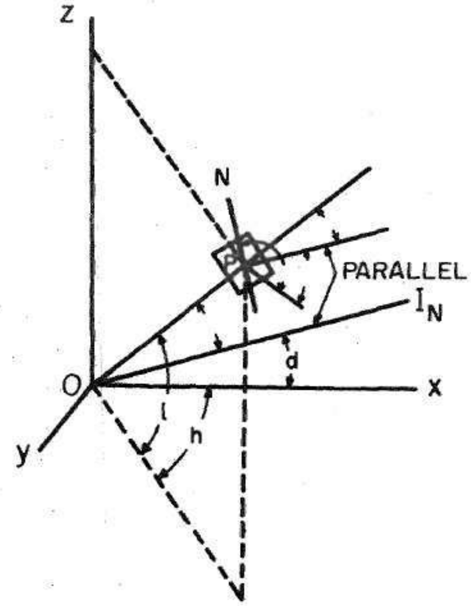


FIGURE 1A RELATION OF A POINT ON THE EARTH'S SURFACE TO SUN'S RAYS.

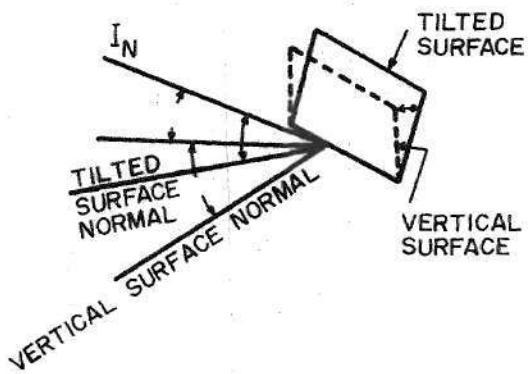


FIGURE 2A RELATION OF SUN'S RAYS TO A TILTED SURFACE.

must be given to correct signs for the latitude and declination angles. If north latitudes are considered positive and south latitudes negative, the declination will be positive for the summer period between the vernal equinox and autumnal equinox (March 22 to September 22, approximately) and negative at other times. The hour angle is measured on either side of solar noon. Thus, h is limited to values between zero and π. If $h < \pi/2$, cos h is positive, and if $h > \pi/2$, cos h is negative. Calculation for the sun's zenith angle is made by equation (1A) and for the altitude angle by equation (2A).

Figure 7 shows a surface tilted by an angle ϕ from the vertical position. The angle of incidence is θ and the wall-solar azimuth is indicated as α. For the tilted surface, we may derive

$$\cos\theta = \cos\beta \cos\alpha \cos\phi + \sin\beta \sin\phi \tag{4A}$$

If the surface is vertical ($\phi = 0$), then

$$\cos\theta = \sin\beta = \cos\psi \tag{5A}$$

If the surface is horizontal ($\phi = \pi/2$), then

$$\cos\theta = \cos\beta \cos\alpha \tag{6A}$$

Thus for a vertical surface, the incidence angle is equal to the zenith angle.

APPENDIX C

SAMPLE CALCULATION

Illustration 1

Find I_t on the roof with 30° slope that faces SE at 4:00 p.m. solar time on July 21, 40° N latitude.

Solution

$$D = 31 + 28 + 31 + 30 + 31 + 30 + 21 = 202$$

July 21 is 202 days from January 1st.

Input Data

Orientation = SE

LST = 4:00 p.m.

$\ell = 40° \text{ N}$

$\phi = 30°$

A = 344

B = .207

C = .136

GR = 20%

D = 202

Declination (d)

$$d = 23.5 \sin\left(\frac{360}{365}(D-80)\right)$$

$$d = 23.5 \sin\left(\frac{360}{365}(202-80)\right)$$

$$d = 23.5 \sin(120.33) = 23.5 \sin(180-59.67) = 23.5 \sin 59.67$$

$d = 23.5 \times .8634$

$d = 20.29$ degrees

Hour angle (h)

$4{:}00 \times 60 = 240$ minutes from noon

$h = .25\ (240) = 60°$

$h = 60$ degrees

Altitude angle (β)

$\sin\beta = \cos\ell \cos h \cos d + \sin\ell \sin d$

$\sin\beta = \cos(40)\cos(60)\cos(20.29) + \sin(40)\sin(20.29)$

$= (.766)(.5)(.9379) + (.643)(.347) = .3592157$

$+ .223121$

$= .5823367$

$= 35.6$ degrees

Azimuth angle (γ)

$\cos\gamma = \sec\beta\ (\cos d \sin\ell \cosh - \cos\ell \sin d)$

$$\cos\gamma = \frac{1}{\cos(35.6)} [\cos(2.29)\sin(40)\cos(60) - \cos(40) \sin(20.29)]$$

$$= \frac{1}{.8131} (.93789 \times .643 \times .5 - .766 \times .34694)$$

$$= \frac{+.0357756}{.8131}$$

$\cos\gamma = .044 = \cos(90 - 2.55) = \cos 87.45$

$\gamma = 180 \pm 87.45 = 92.55$ degrees

Wall-solar azimuth (α)

$\alpha = \gamma - 45 = 92.55 - 45 = 47.55$ degrees

Incident angle (θ)

$\cos\theta = \cos\beta \cos\alpha \cos\phi + \sin\beta \sin\phi$

$$= \cos(35.6)\ \cos(47.55)\ \cos(30) + \sin(35.6)$$

$$\sin(30)$$

$$= .8131 \times .675 \times .866 + .5835 \times .5$$

$$= .47529 + .29175$$

$$\cos\theta = .767$$

$$\theta = 39.9 \text{ degrees}$$

<u>Direct normal solar intensity (I_{DN})</u>

$$I_{DN} = \frac{A}{\exp(\frac{B}{\sin\beta})}$$

$$I_{DN} = \frac{344}{e^{(.207/\sin 35.6)}} = \frac{344}{e^{(.207/.5835)}} = \frac{344}{e^{(.3547557)}} =$$

$$\frac{344}{1.425833}$$

$$= 241.26$$

$$I_{DN} = 241.26 \text{ Btu/hr-ft}^2$$

<u>The angle factor from the roof to the ground (F_{sg})</u>

$$F_{sg} = \frac{1-\cos\phi}{2} = \frac{1-\cos 30}{2} = \frac{1-.866}{2} = .067$$

<u>The angle factor from roof to the sky (F_{ss})</u>

$$F_{ss} = 1-F_{sg} = 1-.067 = .933$$

<u>Diffuse radiation from sky falling on the roof (I_{ds})</u>

$$I_{ds} = CI_{DN}F_{ss}$$

$$= (.136)(241.26)(.933)$$

$$I_{ds} = 30.61 \text{ Btu/hr-ft}^2$$

Intensity of the solar radiation falling on the ground (I_{tH})

$$I_{tH} = I_{DN}\ (C + \sin\beta)$$
$$= 241.26\ (.136 + .5835)$$
$$I_{tH} = 173.59\ \text{Btu/hr-ft}^2$$

Ground-reflected radiation falling on the roof (I_{dg})

$$I_{dg} = (I_{tH})(GR)(F_{sg})$$
$$= (173.59)(.20)(.067)$$
$$I_{dg} = 2.33\ \text{Btu/hr-ft}^2$$

Total solar radiation falling on the roof (I_t)

$$I_t = I_{DN} + I_{ds} + I_{dg}$$
$$I_t = 241.26 + 30.61 + 2.33 = 274.2\ \text{Btu/hr-ft}^2$$

Illustration 4

Find the solar heat gain of a double-glazed window consisting of an outdoor light of 1/4 in clear plate/float glass and an indoor light of 1/4 in clear plate/float glass with reflective film on the no. 3 surface in a west wall at 40° N latitude at 4:00 p.m. on July 21. Outdoor air is 105°F and indoor air is 75°F. Solar intensity = 249.6 Btu/hr-ft^2.

Solution

Input data:

$R_{go} = R_{gi} = .035$

$L = 40°$ N

LST = 4:00 p.m.

$T_o = 105°F$

$T_i = 75°F$

I_t = 249.6 Btu/hr-ft^2

SHGF = 216

τ_o = .80

ρ_1 = .007

ρ_2 = .07

α_1 = .13

α_2 = .13

e_1 = .90

e_2 = .90

τ_i = .12

ρ_3 = .70

ρ_4 = .07

α_3 = .18

α_4 = .81

e_3 = .10

e_4 = .90

h_o = 4.0

h_i = 1.46

h_s = .549

(1) Absorption for glasses in the double-glazed position

$$\alpha_o = \alpha_1 + (\alpha_2)\left(\frac{\tau_o\rho_3}{1-\rho_2\rho_3}\right)$$

$$= .13 + (.13)\left(\frac{.80x.70}{1-.07x.70}\right) = .207$$

$$\alpha_i = (\alpha_3)\left(\frac{\tau_o}{1-\rho_2\rho_3}\right)$$

$$= .18\ \left(\frac{.80}{1-.07x.70}\right) = .151$$

(2) The solar radiation absorbed

$$\alpha I_o = I_t\alpha_o$$

$$= 249.6\ x\ .207 = 51.7\ \text{Btu/hr-ft}^2$$

$$\alpha I_i = I_t\alpha_i$$

$$= 249.6\ x\ .151 = 37.7\ \text{Btu/ft}^2$$

(3) Overall heat transfer coefficient

$$U = \frac{1}{\frac{1}{h_o} + R_{go} + \frac{1}{h_s} + R_{gi} + \frac{1}{h_i}}$$

$$= \frac{1}{\frac{1}{4.0} + .035 + \frac{1}{.549} + .035 + \frac{1}{1.46}} = .355$$

(4) The inward radiation and convection gain for double-glazed unit is:

$$q_{RCi} = U\left(\frac{\alpha I_o}{h_o} + \alpha I_i\ \left(\frac{1}{h_o} + \frac{1}{h_s}\right) + t_o - t_i\right)$$

$$= .355\ (\frac{51.7}{4.0} + (37.7)(\frac{1}{4.0} + \frac{1}{.549}) + 105\text{-}75)$$

$$= .355\ (120.965)$$

$$q_{RCi} = 42.9\ \text{Btu/hr-ft}^2$$

(5) Glass temperatures

$$t_{go} = t_o + (\alpha I_o + \alpha I_i - q_{RCi})(\frac{1}{h_o} + \frac{R_{go}}{2})$$

$$= 105 + (51.7 + 37.7 - 42.9)(\frac{1}{4.0} + \frac{.35}{2})$$

$$= 105 + (46.5)(.2675)$$

$$= 105 + 12.44$$

$$t_{go} = 117.44°F$$

$$t_{gi} = t_i + q_{RCi}\ (\frac{1}{h_i} + \frac{R_{gi}}{2})$$

$$= 75 + 42.9\ (\frac{1}{1.46} + \frac{.035}{2}) = 75 + 30.13$$

$$t_{gi} = 105.13°F$$

(6) Transmitted radiation through both glasses is

$$\bar{\tau} = \frac{\tau_o \tau_i}{(1-\rho_2 \rho_3)}$$

$$= \frac{.80x.12}{1-.07x.70}$$

$$= .101 \text{ Btu/hr-ft}^2$$

(7) The solar heat gain coefficient. For double-glazing glass

$$F = \bar{\tau} + \frac{U\alpha_o}{h_o} + [(U/h_o) + (U/h_s)]\alpha_i$$

$$= .101 + (\frac{.355x.207}{4.0}) + [(\frac{.355}{4.0} + \frac{.355}{.549})] \text{ x } .151$$

$$= .101 + .018 + .111$$

$$F = .23$$

(8) Shading coefficient

$$SC = 1.15 \text{ (F of fenestration)}$$

$$= 1.15\ (.23)$$

$$SC = .265$$

(9) The solar heat gain is

$$q_A = (SC)(SHGF) + U(t_o - t_i)$$

$$q_A = .265 \times 216 + .355\ (105\text{-}75) = 57.24 + 10.65$$

$$q_A = 67.89\ \text{Btu/hr-ft}^2$$

Illustration 2

Find the sol-air temperature at 8:00 a.m. solar time on July 21, 40 degrees N latitude for light construction. Outside temperature is 77 degrees.

Solution

$t_o = 77°F$

$\alpha/h_o = .15$

SHGF for 8:00 a.m. solar time on July 21, 40° N latitude for nine known orientations are listed below:

N	NE	E	SE	S	SW	W	NW	Hor.
28	148	216	160	29	26	26	26	145

for vertical surfaces

$$t_e = t_o + .15\ (1.15\ (\text{SHGF}))$$

$$t_e = t_o + .1725\ (\text{SHGF})$$

for horizontal surfaces

$$t_e = t_o + .1725\ (\text{SHGF}) - 7$$

North

$$t_e = 77 + .1725(28) = 81.83$$

<u>NE</u>

$$t_e = 77 + .1725\ (148) = 102.53$$

<u>E</u>

$$t_e = 77 + .1725\ (216) = 114.26$$

<u>SE</u>

$$t_e = 77 + .1725\ (160) = 104.6$$

<u>S</u>

$$t_e = 77 + .1725\ (29) = 82$$

<u>SW</u>

$$t_e = 77 + .1725\ (26) = 81.485$$

<u>W</u>

$$t_e = 77 + .1725\ (26) = 81.485$$

<u>NW</u>

$$t_e = 77 + .1725\ (26) = 81.485$$

<u>Horizontal surface</u>

$$t_e = 77 + .1725\ (145) - 7 = 95.$$

Sol-air temperature on July 21, 40 degrees North latitude

Time LST	Temp °F	N	NE	E	SE	S	SW	W	NW	Hor.
8	77	81.83	102.53	114.26	104.6	82	81.485	81.485	81.485	95

Illustration 3

Find the heat gain by conduction through the exterior wall with known specification, using the transfer function method.

Wall construction: 3/4 in indoor plaster + 2 in insulation + 4 in heavy concrete (air space between the plaster and insulation)

Outdoor surface resistance = .333 (hr)(ft^2)(°F)/Btu

Indoor surface resistance = .685 (hr)(ft^2)(°F)/Btu

$A = 1.0\ ft^2$

With sol-air temperature listed in the table below for July 21 at 40° North latitude-West

$$\alpha/h_o = 0.15$$

Room Temperature = 75°F assuming that the daily sol-air temperature cycle repeated for several consecutive days.

Find: the heat gain through one ft^2

Solution

The calculation of heat gain for a particular time requires information on the values of the sol-air temperature at that and preceding times,,as well as the heat flow at preceding times. Initially, the history of the heat flow is unknown, but it can be assumed zero to start the calculations. The effect of this assumption on the calculated heat flow values becomes negligible as the calculation re repeated for successive 24-hour cycles. For the problem, the assumed sol-air temperature values, t_e, are:

time, hr	t_e, °F	time, hr	t_e, °F	time, hr	t_e, °F
1	76	9	85	17	127
2	76	10	89	18	114
3	75	11	93	19	87
4	74	12	97	20	85
5	74	13	110	21	83
6	75	14	121	22	81
7	78	15	129	23	79
8	81	16	131	24	77

and $t_{e,\tau} = t_{e,\tau-24}$ for $\tau > 24$

The heat transfer coefficients of the wall under consideration (4 in concrete + 2 in insulation on the outside) listed in reference 3, table 39, item 32, are:

$n = 0 \quad b_0 = .00055, \; d_0 = 1.00000$

$n = 1 \quad b_1 = .00735, \; d_1 = -.94420 \qquad U = .122$

$n = 2 \quad b_2 = .00482, \; d_2 = .05025 \qquad \sum_{n=o} C_n = .01293$

$n = 3 \quad b_3 = .00021, \; d_3 = .00008$

$$q_{e,} = A\left(\sum_{n=o} b_n (t_{e,\tau-n\Delta}) - \sum_{n=1} d_n \left(\frac{q_{e,\tau-n\Delta}}{A}\right) - t_{rc} \sum_{n=o} C_n\right)$$

i.e.

$$\frac{q_{e,\tau}}{A} = \begin{matrix} b_0(t_{e,\tau}) \\ +b_1(t_{e,\tau-\Delta}) \\ +b_2(t_{e,\tau-2\Delta}) \\ \vdots \end{matrix} \quad - \quad \begin{matrix} d_1(\frac{q_{e,\tau-\Delta}}{A}) \\ +d_2(\frac{q_{e,\tau-2\Delta}}{A}) \\ \vdots \end{matrix} \quad - \quad [t_{rc} \sum_{n=o} C_n]$$

τ = 1 hr

$$q_{e,1} = \begin{matrix} .00055(76) \\ +.00735(77) \\ +.00482(79) \\ +.00021(81) \end{matrix} \quad - \quad \begin{matrix} -.94420(0) \\ +.05025(0) \\ +.00008(0) \end{matrix} \quad - \quad [75(.01293)] =$$

$$= (.0418 + .56595 + .38078 + .01701) - (0) - (.96975) =$$

$$= .03579 = .036 \text{ Btu/hr-ft}^2$$

Note: (1) The reason for choosing the values of $t_{e,\tau-n\Delta}$) is that current temperature is multiplied by b_0 coefficient, the sol-air temperature of one step in time earlier is multiplied by b_1 and two steps in time earlier is multiplied by b_2, etc. (2) In the second part, the sum of the products of d coefficients and the previous values of heat gain. The first d coefficient used is d_1. Again the order of values is the same as in the first term, i.e., d_1 is multiplied by the heat gain value that was calculated for the previous step in time, d_2 is multiplied by the value calculated for two steps back in time, etc. In our first calculation above (τ = 1 hr), the values are zero. (3) The third term is constant, since room air temperature is constant and needs to be calculated once. Therefore, for the rest of our calculation, the third term would be .96975.

<u>τ = 2 hrs</u>

$$q_{e,2} = \begin{array}{r} .00055(76) \\ +.00735(76) \\ +.00482(77) \\ +.00021(79) \end{array} \quad - \quad \begin{array}{r} -.94420(.036) \\ +.05025(0) \\ -.00008(0) \end{array} \quad - (.96975) =$$

$$= (.0418 + .5586 + .37114 + .01659) + .03399 - .96975$$

$$= .5237 = .52 \text{ Btu/hr-ft}^2$$

<u>τ = 3 hrs</u>

$$q_{e,3} = \begin{array}{r} .00055(75) \\ +.00735(76) \\ +.00482(76) \\ +.00021(77) \end{array} \quad - \quad \begin{array}{r} -.94420(.052) \\ +.05025(.036) \\ -.00008(0) \end{array} \quad - (.96975) =$$

$$= (.04125 + 5586 + .36632 + .1617) - (-.04910 + .00181)$$
$$- 96975$$

$$= .05988 = .060 \text{ Btu/hr-ft}^2$$

<u>τ = 4 hrs</u>

$$q_{e,4} = \begin{matrix} .00055(74) \\ +.00735(75) \\ +.00482(76) \\ +.00021(76) \end{matrix} - \begin{matrix} -.9442(.060) \\ +.05025(.052) \\ -.00008(.036) \end{matrix} - (.96975) =$$

$$= (.0407 + .55125 + .36632 + .01596) - (-.5665 + .00261 - - .000003) - .96975 = .058523 = .059 \text{ Btu/hr-ft}^2$$

<u>τ = 5 hrs</u>

$$q_{e,5} = \begin{matrix} .00055(74) \\ +.00735(74) \\ +.00482(75) \\ +.00021(76) \end{matrix} - \begin{matrix} -.94420(.059) \\ +.05025(.060) \\ -.00008(.052) \end{matrix} - (.96975) =$$

$$= (.0407 + .5439 + 3615 + .01596) - (-.05571 + .00302 - - .000004) - (.96975) = .045 \text{ Btu/hr-ft}^2$$

The values of q_c for this example are listed in the table on the following page.

Illustration 5

Find the cooling load of a room with known specifications, using the transfer function method.

(1) Room with 1/2 inch air space double-glazed window

(2) Shading coefficient = .83

(3) Heavy weight construction and 8 ft floor to ceiling height

(4) At 40° North latitude, date June 21

Summary of Calculations for $q_{e,\tau}$

τ	$q_{e,\tau}$	τ	$q_{e,\tau}$	τ	$q_{e,\tau}$	τ	$q_{e,\tau}$
1	.036	25	2.134	49	2.254	73	2.261
2	.052	26	1.915	50	2.022	74	2.028
3	.060	27	1.714	51	1.809	75	1.814
4	.059	28	1.527	52	1.611	76	1.616
5	.045	29	1.348	53	1.422	77	1.427
6	.027	30	1.184	54	1.250	78	1.254
7	.020	31	1.047	55	1.106	79	1.109
8	.043	32	.954	56	1.006	80	1.009
9	.103	33	.912	57	.959	81	0.962
10	.206	34	.924	58	.966	82	0.968
11	.352	35	.989	59	1.026	83	1.028
12	.536	36	1.101	60	1.134	84	1.136
13	.759	37	1.261	61	1.290	85	1.292
14	1.082	38	1.528	62	1.554	86	1.555
15	1.525	39	1.921	63	1.943	87	1.945
16	2.042	40	2.393	64	2.414	88	2.415
17	2.562	41	2.874	65	2.892	89	2.893
18	3.001	42	3.278	66	3.294	90	3.295
19	3.261	43	3.507	67	3.521	91	3.521
20	3.221	44	3.439	68	3.452	92	3.452
21	3.022	45	3.215	69	3.226	93	3.227
22	2.804	46	2.976	70	2.986	94	2.987
23	2.583	47	2.738	71	2.745	95	2.745
24	2.359	48	2.495	72	2.503	96	2.503

(5) Window orientation NW

(6) Window area is 50% of exterior wall (i.e. $A = 4\ ft^2$/linear foot of exterior wall)

(7) $U_{window} = .56\ Btu/hr\text{-}ft^2\text{-}°F$

$U_{exterior\ wall} = .25\ Btu/hr\text{-}ft^2\text{-}°F$

$U_{corridor\ wall} = .22\ Btu/hr\text{-}ft^2\text{-}°F$

(8) Solar heat gain (SHG) = $Btu/hr\text{-}ft^2$

Solar heat gain factor (SHGF) = $Btu/hr\text{-}ft^2$

SHG = SHGF (shading coefficient) (area/linear foot of exterior wall) = SHGF (.83)(4)

SHG = SHGF (3.32) (α)

Calculate the cooling load due to solar radiation/linear foot exterior wall.

Time Hr.	SHGF from Table 4 for June 21, $Btu/hr\text{-}ft^2$	SHG Btu/ft
1-4	0	0 x 3.32 = 0
5	1	1 x 3.32 = 3.32
6	12	12 x 3.32 = 39.84
7	20	20 x 3.32 = 66.40
8	26	26 x 3.32 = 86.32
9	31	31 x 3.32 = 102.92
10	35	35 x 3.32 = 116.20
11	37	37 x 3.32 = 122.84
12	38	38 x 3.32 = 126.16
13	40	40 x 3.32 = 132.80
14	62	62 x 3.32 = 205.84
15	113	113 x 3.32 = 375.16
16	156	156 x 3.32 = 517.92
17	172	172 x 3.32 = 571.04
18	142	142 x 3.32 = 471.44
19	21	21 x 3.32 = 69.72
20-24	0	0 x 3.32 = 0
	Daily total =	3007.92

$SHG_r = SHG_{r-24}$ for $r>24$

Solution

To find the coefficients of room transfer functions from Table 44, page 434, reference 3, choose the heavy construction under the solar (radiation) heat gain through glass with no interior shading device.

$V_o = .2155$ $\omega_o = 1.0000$

$V_1 = -.3712$ $\omega_1 = -2.2908$

$V_2 = .1790$ $\omega_2 = 1.7252$

$V_3 = -.0160$ $\omega_3 = -.4277$

These values of V must be adjusted to account for the heat loss from the room as follows:

The specification that window area is 50% of exterior wall area gives 4 ft^2 of glass/linear foot of exterior wall. Using the surface area of the given U-values, the total conductance/linear foot of exterior wall from equation (63) is:

$$K_T = \frac{1}{L_F} (U_w A_w + V_{ow} A_{ow} + U_c A_c) \text{ Btu/hr-ft-°F}$$

$K_T = \frac{1}{1}$ (.56 x 4--conductance/linear foot of window

+ .25 x 4 conductance/linear foot of opaque exterior wall

+ .22 x 8) conductance/linear foot of corridor wall

K_T = 5.00 Btu/hr-ft^2-°F/ft conductance/linear foot of room length

From Figure 11 at $K_T = 5.00$ and using curve 1, the value of $F_c = .902$. Therefore, the adjusted values of V are

$V_o = .902\ (.2155) = .1944$ $\quad \omega_o = 1.0000$

$V_1 = .902\ (-.3712) = -.3348$ $\quad \omega_1 = -2.2408$

$V_2 = .902\ (.1790) = .1615$ $\quad \omega_2 = 1.7252$

$V_3 = .902\ (-.0166) = -.0150$ $\quad \omega_3 = -.4277$

The cooling load component due to solar radiation at any time τ is given by equation (61)

$$Q_r = \sum_{i=1} (V_o q_{e,r} + V_1 q_{e,r-\Delta} + V_2 q_{e,r-2\Delta} + \cdots - {}_1Q_{r-\Delta} - {}_2Q_{r,2\Delta} - {}_3Q_{r-3\Delta} \cdots)$$

or it can be set up as follows:

$$\begin{aligned} Q_r = \ & V_o(SHG_r) \\ & + V_1(SHG_{r-\Delta}) \\ & + V_2(SHG_{r-2\Delta}) \\ & + V_3(SHG_{r-3\Delta}) \\ & - \omega_1(Q_{r-\Delta}) \\ & - \omega_2(Q_{r-2\Delta}) \\ & - \omega_3(Q_{r-3\Delta}) \end{aligned}$$

As in the earlier heat gain problem, the calculation is started by assuming that the previous Q's are zero. Furthermore, in this example, since SHG = 0, τ = 1,2,3 and 4, therefore Q's in Btu/hr-ft are:

$$Q_1 = 0$$
$$Q_2 = 0$$
$$Q_3 = 0$$
$$Q_4 = 0$$

Q_5 =	.1944 (3.32)	.6454
	-.3348 (0)	-0
	+.1615 (0)	+0
	-.0150 (0)	-0
	+2.2908 (0)	+0
	-1.7252 (0)	-0
	+.4277 (0)	+0
		$\overline{Q_5 = .6454}$ Btu/hr-ft
Q_6 =	.1944 (39.84)	7.7449
	-.3348 (3.32)	-1.1115
	+.1615 (0)	+0
	-.0150 (0)	-0
	+2.2908 (.6454)	+1.4785
	-1.7252 (0)	-0
	+.4277 (0)	+0
		$\overline{Q_6 = 8.1119}$ Btu/hr-ft

Q_7 = .1944 (66.40)	12.9082
-.3348 (39.84)	-13.3384
+.1615 (3.32)	+ .5362
-.0150 (0)	-0
+2.2908 (8.1119)	+18.5827
-1.7252(.6454)	- 1.1134
+.4277 (0)	+0
	Q_7 = 17.5753 Btu/hr-ft

Q_8 = .1944 (86.32)	16.7806
-.3348 (66.40)	-22.2307
+.1615 (39.84)	+ 6.4342
-.0150 (3.32)	- .0498
+2.2908 (17.5753)	+40.2615
-1.7252 (8.1119)	-13.9946
+.4277 (.6454)	+ .2760
	Q_8 = 27.4772 Btu/hr-ft

Q_9 = .1944 (102.92)	20.0076
-.3348 (86.32)	-28.8999
+.1615 (66.40)	+10.7236
-.0150 (39.84)	- .5976
+2.2908 (27.4772)	+62.9448
-1.7252 (17.5753)	-30.3209
+.4277 (8.1119)	+ 3.4695
	Q_9 = 37.3271 Btu/hr-ft

Values of Q_r for the remainder of the calculations are listed in the table below. The calculations of Q_r are terminated at τ = 96 hr because by that time the effect of the assumed zero initial conditions has decayed to negligible proportions.

τ	Q_r	τ	Q_r	τ	Q_r	τ	Q_r
1	0	25	60	49	71	73	73
2	0	26	54	50	64	74	66
3	0	27	50	51	59	75	61
4	0	28	46	52	54	76	56
5	0.6	29	43	53	51	77	52
6	8	30	47	54	55	78	56
7	17	31	54	55	61	79	62
8	27	32	61	56	68	80	69
9	37	33	69	57	75	81	76
10	47	34	76	58	82	82	83
11	55	35	82	59	87	83	88
12	61	36	87	60	92	84	93
13	67	37	91	61	96	85	97
14	86	38	109	62	113	86	114
15	131	39	152	63	156	87	157
16	187	40	201	64	210	88	211
17	234	41	252	65	256	89	256
18	248	42	265	66	268	90	268
19	184	43	200	67	203	91	204
20	139	44	153	68	156	92	157
21	110	45	124	69	127	93	127
22	91	46	104	70	106	94	107
23	77	47	89	71	92	95	92
24	67	48	79	72	81	96	81

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